Final Report

Integration of Energy Storage with Seawater Air Conditioning (SWAC) Systems

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For the

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Executive Summary

Objective

The ultimate objective of this project is to commercialize one, or more, Seawater Air Conditioning (SWAC) or SWAC/Energy Storage Hybrid Systems in Hawaii, with the potential for technology export to other areas.

Description of Project

During the SWAC study ("Sea Water Air Conditioning Feasibility Analysis"), conducted under a previous State Energy Program (SEP) Grant, the SWAC Project Team identified a number of potential SWAC projects on Oahu.

It was (and continues to be) the general consensus that the best system for Hawaii (and probably for other areas where deep water cooling technology might be marketed, such as the Great Lakes) is a hybrid SWAC/Energy Storage system. (This conclusion has been confirmed by independent analyses by The Cool Solutions Company of deep lake water DC systems.) This hybrid conceptual approach allows the SWAC system to supply a much larger base load cooling demand (for a given pipe size and cost), while the energy storage system can supply the peak demand. A smaller energy storage system is also able to provide peaking capabilities for a much larger district cooling system. Utility demand during peak demand periods is reduced significantly and energy use is reduced by 75 to 90%. It also allows the use of an enormous renewable energy resource -- cold, deep seawater. Thus, the hybrid system provides superior benefits than either system alone, and at a lower cost, with enhancements to both unit capital costs and life cycle owning and operating costs.

The project addressed in the current report is a follow-up to the SWAC project and investigated the technical and economic feasibility, and the costs and benefits, of incorporating energy storage systems into SWAC DC systems. The reduced energy requirements, the reduced utility generation demand, and the increased local economic development benefits of such hybrid systems are enormous for Hawaii.

Work Plan Employed for Execution of the Scope of Services

We have undertaken and performed the authorized and designated activities, detailed in the following sections of this report, in close cooperation and coordination with the DBEDT Project Manager, Dr. David Rezachek.

Major Findings

SWAC DC systems were confirmed to offer attractive or competitive life cycle cooling costs with conventional in-building chiller systems.

Optimal integration of Thermal Energy Storage (TES) with SWAC DC systems will generally reduce total life cycle cooling costs by 10 to 15% relative to non-TES SWAC DC systems.

A 40,000 ton SWAC-TES DC system serving the combined areas of the downtown Honolulu waterfront, Kakaako, and Waikiki can be developed in phases employing two seawater intake systems, two packaged chiller plants and two stratified chilled water TES tanks. Projected economics are improved by 12% versus non-TES SWAC DC systems and by 28% versus conventional in-building chilling systems.

Other potential SWAC developments will also benefit from the integration of TES.

The technologies needed for all aspects of the system are mature and proven.

Marketing and financing will be challenges; but as in the case of other DC developments, those challenges can be successfully overcome with appropriate approaches. A public-private partnership could significantly aid in the initiation of a timely and aggressive commercialization effort.

The benefits of SWAC will accrue in many areas to many stakeholders. As an example, the 40,000 ton SWAC DC development on the South Shore of Oahu will provide the following:

- Efficient, renewable, and reliable cooling service for 16 million sq ft of facilities
- Approximately 75% savings in electrical energy for cooling (150 million kWh/yr)
- Comparable reductions in CO_2, refrigerants, and air & water pollutants
- 30 megawatt (approximately 2%) reduction in Hawaii's total peak electric power demand
- Avoidance of 336,000 barrels of imported oil equivalent per year
- A projected 10 to 20% reduction in life-cycle cooling cost for customers
- A projected 15% Return-on-Equity for equity investors
- Over $130 million in construction project spending
- Local tax revenues and potential franchise fees
- Numerous local auxiliary uses of the cool effluent seawater.

Realistic commercial potential for SWAC in Hawaii is ultimately at least 50,000 to 100,000 tons.

Recommendations

1. TES should be integrated with SWAC DC system designs to enhance overall economics.
   - The primary focus when integrating TES with SWAC DC systems should be to minimize capital cost per peak ton of installed system cooling capacity.
   - The siting of TES should consider strategic locations, remote from chilling sources.

2. Much of the initial SWAC development effort should be focused on the high cooling density areas along Oahu's South Shore.

3. Other SWAC opportunities should be addressed, including interested large customers (such as the DOD) and unique situations (such as large new commercial real estate developments, large future combustion turbine power plants, and any developments near NELHA on the Big Island).

4. An effective public-private partnership should be identified and developed. Seed funding should be sought and obtained.

5. Various mechanisms (e.g. investment tax credits, Act 221 tax credits, and TES tax credits, as well as bonus depreciation schedules, utility demand-side management rebates, and federal energy production incentives) each could generate very significant further enhancements to SWAC-TES DC project economics. These mechanisms should be investigated in enough detail:
   - to define which may be realistic,
   - to quantify the value to be gained, and
   - to identify the necessary steps to ensure that the value is indeed captured.

6. The technology is so ready for deployment, and benefits are so substantial and apply to so many stakeholders, that SWAC-TES DC systems should be actively supported and pursued in Hawaii, to realize the vision of 50,000 to 100,000 tons of installed system capacity.

1.0 Review and Analysis of the Sea Water Air Conditioning Feasibility Analysis Final Report ("SWAC Report")

1.1 Review the SWAC Report to verify design, economic, and operational assumptions used; especially with respect to District Cooling (DC) and incorporation of Thermal Energy Storage (TES).

1.2 Identify one, or more, potential SWAC systems that might benefit from incorporation of TES. This involved detailed consideration of the characteristics of the potential SWAC systems presented in the SWAC report.

1.3 Provide a brief summary of this review and analysis, including conclusions and recommendations.

The SWAC Report was reviewed and the design, economic and operational assumptions were verified, especially with respect to District Cooling (DC) aspects of the study and the incorporation of Thermal Energy Storage (TES). Several potential SWAC DC systems have been identified that will benefit from the incorporation or optimization of TES.

The design and cost methodology and the values employed in the SWAC study have been confirmed to be generally consistent with commercial District Cooling experience.

Regarding the incorporation of TES, for low temperature TES systems such as ice TES or Low Temperature Fluid TES, if employed, it will be necessary to supplement the SWAC cooling system with auxiliary low temperature chillers for charging TES.

For chilled water TES, SWAC can directly recharge TES; however, the projected supply-to-return chilled water temperature differential is relatively small, which results in larger TES volumes, and a higher TES cost, than would be the case with the higher supply-to-return temperature differentials typically utilized in District Cooling applications. Larger Delta Ts could be achieved through the use of auxiliary chillers (as with the low temp TES systems). Alternatively, larger Delta Ts could be achieved through modifications to the SWAC system. For example, longer SWAC intake pipes, reaching to deeper, colder water, could be used to lower the DC supply temperature. And some secondary uses of the warm DC return water could be used to raise the return water temperature. Accordingly, it may be appropriate to re-evaluate the optimal supply and return temperatures of the SWAC system in light of the incorporation of TES, to yield the optimum system economics for the integrated SWAC-TES-DC system.

If auxiliary chillers are incorporated (either for the necessity of charging low temp TES systems or for the purpose of expanding chilled water Delta T for chilled water TES systems), those same chillers can serve other important functions for enhancing the commercial development of SWAC DC systems. Specifically, the auxiliary chillers can serve as potential peaking cooling capacity and/or as emergency back-up cooling capacity. Such attributes can not only improve system economics in some cases, but may provide capacity redundancy deemed essential for customer marketing success.

Even without the optimized integration of TES into the SWAC DC systems evaluated in the SWAC report, several of the SWAC systems were projected to exhibit attractive economics versus conventional air-conditioning systems, when evaluated on a life cycle cost basis. The optimized use of TES will improve the economics of the SWAC systems in every case. This is accomplished through one of the following approaches:

1. The addition of a TES system to the originally envisioned SWAC system (with an associated incremental capital cost increase) and the expansion of the DC system (with an associated incremental capital cost increase), to allow for providing service to a much larger customer load base (increased by approximately 50%)
2. The addition of a TES system to the originally envisioned SWAC system (with an associated incremental capital cost increase) and a large reduction in the size (by approximately 33%) of the originally envisioned SWAC system (with an associated, significant capital cost reduction), to allow for providing service to the originally envisioned customer load base
3. Various combinations of items 1 and 2, above (i.e. the addition of TES, combined with both a somewhat smaller SWAC system and a somewhat larger DC system)

In each of the above three instances, there are two major benefits that result:

1. The investment in the SWAC piping system is much more fully utilized (seeing much higher load factors of usage, both on a daily basis and on an annual basis). Thus, much greater amounts of energy savings, emission reductions, and oil importation avoidance are achieved for a given SWAC piping installation.
2. A lower installed capital cost (per peak ton served) and a lower life cycle cost (per ton-hour delivered) are achieved. This is very significant in that it not only increases savings relative to conventional air-conditioning systems, but by virtue of improving the overall economics of the SWAC DC approach, it is likely to render some SWAC DC installations commercially viable, where they otherwise might not be realized in practice due to various barriers to implementation.

It is therefore recommended that SWAC DC systems be evaluated, wherever practical, with the incorporation of optimized integration of TES. Such an approach will yield the maximum economic value, and improve the chance of commercialization of the SWAC technology, thus helping to actually capture the enormous combination of benefits in the areas of economic value, energy efficiency, environmental emission reductions, and reduced oil-dependence that SWAC promises to deliver.

2.0 Literature Search and TES System Technical Analysis and Evaluation

2.1 Conduct a literature search to identify various types of TES systems that could be used in conjunction with SWAC systems.

2.2 Analyze, evaluate, and summarize this literature.

2.3 Provide conclusions and recommendations regarding which TES systems are best suited for integration into SWAC systems. The analysis will consider chilled water TES, ice TES, and low temperature fluid TES technologies.

A literature search has been conducted to identify the various types of TES systems that can be used in conjunction with SWAC District Cooling systems. The literature is listed in the attached Bibliography in the Appendices of this report. The literature has been grouped into three categories:

- General information on TES and DC
- Specific analyses and cases studies of the use of TES in DC or other large-scale cooling systems
- TES equipment supplier literature and information

Three types of TES technologies are already in successful use in DC systems. The three TES technologies are:

- Ice TES
- Chilled Water (CHW) TES
- Low Temperature Fluid (LTF) TES

Each technology has inherent advantages and limitations for its application to comfort cooling and to District Cooling. These characteristics can be generalized and are presented in simplified form in Table 2.1 below:

Table 2.1 – Inherent Characteristics of TES Technologies

	Ice	CHW	LTF
Volume	good	poor	fair
Footprint	good	fair	good
Modularity	excellent	poor	good
Economy-of-Scale	**poor**	**excellent**	**good**
Energy Efficiency	fair	excellent	good
Low Temp Capability	good	poor	excellent
Ease of Retrofit	**poor**	**excellent**	**fair**
Rapid Discharge Capability	poor	good	good
Simplicity and Reliability	fair	excellent	good
Site Remotely from Chillers	**poor**	**excellent**	**excellent**
Dual-Use as Fire Protection	poor	excellent	poor
Suited to recharge via SWAC	**poor**	**excellent**	**poor-fair**

It is noteworthy that each TES technology exhibits characteristics that range from excellent to poor. Accordingly, it is important both to understand the needs of each application and to select a TES technology that is best suited to meet those needs. Those characteristics that are likely to be of greatest importance for SWAC DC applications are the items shown in bold typeset within the table above. A review of those items clearly points to the use of chilled water TES as being generally the most advantageous TES technology for SWAC DC systems.

Due to the economy-of-scale inherent to the sensible heat TES systems (chilled water and LTF TES), such systems will be strongly preferred on a capital cost basis for large applications such as DC systems in general and SWAC DC systems in particular. However, ice TES does offer the significant advantage of reduced volumetric space requirements for the storage element. LTF systems exhibit a volumetric space requirement that is intermediate to those of ice TES and chilled water TES.

Furthermore, due to the available seawater supply temperatures, only the chilled water TES system can be recharged directly with seawater cooling, without the use of additional supplementary mechanical chilling equipment. However, should supplementary equipment be required for other reasons (e.g. for peaking and/or back-up cooling capacity), such auxiliary cooling equipment could be selected to accommodate the use of either ice TES or LTF TES. However, in many instances, it is anticipated that such auxiliary peaking and/or back-up cooling capacity would be provided by existing conventional chillers already located at some of the SWAC DC customer facilities. In those cases, the chillers would always be capable of recharging chilled water TES, and may be capable of recharging LTF TES, but are generally not suitable for recharging ice TES.

Finally, ice TES recharging chillers must be located within a short distance of the ice storage elements themselves. Chilled water TES can be located anywhere along (or reasonably nearby to) the DC system's distribution piping network. In this case, TES can be sited strategically and used effectively to peak shave or enhance not only the peak cooling generation capacity but also the peak distribution system capacity. LTF TES can also be located remotely from the LTF chillers, but only if the interconnecting distribution system also utilizes the LTF as its heat transfer medium. It is noteworthy however that the use of the LTF (and its higher supply-to-return temperature differential) within the distribution system will actually improve the capital and operating economics of the DC distribution system. This is accomplished through the ability to use smaller pumps and piping, or to serve greater customer loads with a given size of pumps and piping.

In "Thermal Energy Storage: Solutions for Demand Management" (November 2001), the author has tabulated over 100 instances of the use of TES technologies in DC and other large cooling system applications. Such applications were sub-categorized into 1) private industry cooling systems, 2) university and college DC systems, 3) hospital and medical DC systems, 4) other governmental DC systems, 5) DC utility systems, and 6) Combustion Turbine Inlet Cooling (CTIC) systems. In each grouping, chilled water TES was slightly dominant to overwhelmingly dominant as the choice of TES technology employed. These examples underscore the general applicability of chilled water TES to large cooling systems, even without the important added consideration of the temperature compatibility of SWAC with a given TES technology. Once that final issue is included, chilled water TES is further spotlighted as the likely most suitable choice for SWAC DC systems.

For the above reasons, it is concluded that, at least as the general rule, chilled water TES clearly represents the most advantageous TES technology for use in SWAC DC systems. Of course, in individual cases, there may still be value in exploring and utilizing the alternatives of ice TES and/or LTF TES.

3.0 Preliminary Design of a Typical SWAC/TES Hybrid System

We have relied on past extensive experience in the identification, optimization, and integration of TES into actual DC systems.

3.1 Develop a preliminary facility design for the most promising of the potential SWAC/TES Hybrid Systems.

3.2 Identify major components and subsystems.

3.3 Provide a system layout diagram.

3.4 Develop a construction timetable.

Preliminary Facility Design

The most promising (and the most rewarding, in terms of the delivered benefits) of the identified candidate SWAC/TES hybrid systems is an integrated DC system serving much of the heavily developed commercial areas on the South shore of Oahu, including the areas of the downtown Honolulu Waterfront, Kakaako, and Waikiki. Accordingly, such a system was chosen as the model for the preliminary facility design.

Due to the large size and the large number of customers in such a development, it is expected that the development would necessarily occur over an extended period of time (years), via sequential phases of development. The chosen design approach purposely allows for such a phased development. The approach allows for the management of investment to coincide with system customer load growth, while capturing the benefits of SWAC in each phase, and culminating in a mature system that economically maximizes the achievable goals.

The system design approach integrates SWAC with District Cooling, Thermal Energy Storage, and conventional chiller plant capacity. The integrated system provides the important elements and attributes of modular capacity growth, flexibility of operation, and reliability through ease of redundancy.

District Cooling (DC) is utilized to aggregate the large cooling loads necessary for cost-effective deployment and utilization of large-scale SWAC infrastructure.

Thermal Energy Storage (TES) is employed to maximize the utilization of, and minimize the capital investment in, the expensive SWAC infrastructure. The use of TES in a “load leveling” configuration allows the SWAC piping to be employed at a higher capacity factor and to serve a substantially larger peak customer load.

Chilled water TES was chosen for this design, for the reasons presented in section 2 of this report. Specifically, in the large capacities required for this application, CHW TES offers a much lower initial capital cost than does ice TES (which has relatively little economy of scale). Furthermore, unlike ice TES, the CHW TES allows the TES units to be sited remotely from the system's charging chillers; this permits the TES units to be located strategically on less valuable, less aesthetically sensitive land; also, it allows the TES units to act during discharge as if they were satellite chiller plants, thus avoiding bottle-necks in the DC distribution system, and minimizing the size and cost of DC network piping. Finally, the recharge chillers for CHW TES will be less capital-intensive per ton and consume much lower kW/ton than would the recharge chillers required for an ice TES system. The sole drawback to the CHW TES is its larger storage volume; however, this issue is minimized through the use of a relatively large Delta T and by the strategic remote siting of the TES tanks.

Conventional chiller plant capacity is also incorporated in the system design. This is done primarily because of the importance of achieving a lower chilled water supply (CHWS) temperature than could be achieved using the seawater temperatures available to the Oahu South shore areas. The 3,300 ft (1,000 m) depth, 40 ºF contour is located too remotely from shore for practical and economic use in this area. The 1,600 ft (500 m) depth, 45 ºF contour is the realistic practical limit for SWAC systems serving this area. For effective cooling (and successful marketing of DC services) it is considered necessary to have a deliverable CHWS temperature of no more than 42 ºF, and desirably 40 ºF or cooler.

Accordingly, the design employs conventional chiller plant capacity operating in series with the SWAC seawater-to-CHW heat exchangers (HXs). Available 1,600 ft deep (45 ºF) seawater is drawn from the ocean. The SWAC HXs employ 45.6 ºF seawater to produce 46.5 ºF CHW. Nearby chiller plants further cool the CHW from 46.5 ºF to 39.0 ºF. The 39.0 ºF CHW is delivered into the CHWS headers of the DC network and (during non-peak load periods, generally at night or during cooler weather) to the bottoms of the stratified CHW TES tanks. During peak load periods (generally daytime during hot weather periods), the cold CHW is withdrawn from the bottoms of the TES tanks and pumped into the DC networks CHWS headers to supplement the CHWS simultaneously coming from the SWAC HXs/chiller plants. The design CHWS temperature delivered to customer building interfaces is no more than 39.5 ºF. The design chilled water return (CHWR) temperature for the DC network is 58.0 ºF. This CHWR flows back to the SWAC HXs where the cooling cycle continues.

A secondary, yet very important, benefit of the use of the conventional chillers and their lower CHWS temperature is that the DC system Delta T (the temperature difference between CHWS and CHWR) is dramatically increased from only 10.5 ºF (46.5 / 57.0 ºF) to 18.5 ºF (39.5 / 58.0 ºF). This 76% increase in Delta T equates to a similar % increase in cooling load capacity for a fixed size of DC system piping and pumps, as well as a similar % capacity increase for a fixed volume of TES tanks.

The seawater exiting from the SWAC HXs is 57.0 ºF. This still quite cool seawater is then used as the heat rejection sink for the refrigerant condensers of the conventional chiller plants. This provides several benefits. First, it avoids the need for cooling towers, minimizing or eliminating issues of space, aesthetics, cooling tower plumes, make-up water, chemical treatment, and blow-down. Second, the relatively cold condensing temperature improves the energy efficiency of the chiller plants. And third, it further raises the temperature of the effluent seawater, both before and after the effluent's potential use in other auxiliary applications, thus minimizing the depth, distance, and cost of the effluent discharge lines. Some specific potential auxiliary applications include the use of effluent from the downtown area for cooling at the HECO downtown power plant and the use effluent in the Waikiki area for flushing of the Ala Wai.

The relative cooling capacities of the SWAC HXs and the chiller plants is in proportion to the CHW Delta T across those elements of the system, i.e. in the ratio of 7.5 ºF (across the chillers) to 11.5 ºF (across the SWAC HXs), or a ratio of 0.652 to 1. Thus, for every 10,000 tons of SWAC HX capacity, there will be 6,520 tons of conventional chiller plant capacity.

The ratio of average DC system cooling load over a 24-hour peak design day to peak DC system cooling load during that same design day has been estimated to be 0.70 to 1, or 70%. The inverse of this ratio is 1.4286 to 1. Thus, with an adequately sized TES system, a peak DC system load can be served that is 42.9% larger than the combined capacities of the SWAC HX and chiller plant systems. Therefore, for every 10,000 tons of SWAC HX capacity, there will be not only 6,520 tons of conventional chiller plant capacity, but also (16,520 tons x 0.4286) or 7,080 tons of TES discharge capacity.

The available DC system peak load capacity would be 10,000 tons (from SWAC HXs) plus 6,520 tons (from chiller plants) plus 7,080 tons (from TES discharge), or 23,600 tons total. In other words, **the integrated SWAC/chiller/TES system can serve a peak DC system load that is 2.36 times the instantaneous peak design capacity of the seawater piping and HX system**.

The chosen DC system design load for this preliminary facility design is 39,590 tons. The value was chosen as being 2.36 times the capacity of the combined seawater piping designs previously evaluated for the downtown Honolulu waterfront area (8,465 tons) and the West Waikiki area (8,310 tons). After adding the appropriate capacities of the conventional chiller plants (5,520 tons and 5,420 tons, respectively) and for two TES tanks (11,875 tons combined discharge capacity), the total peak load capability of 39,590 tons is achieved.

The DC customer load total of 39,590 tons is less than the total identified realistic DC load total of 50,000 tons or more. However, it is a very challenging load target and one that can only be achieved over time, and with successful and dedicated marketing and development. Nevertheless, the selected design approach has been purposely selected such that elements of the design can be implemented in phases to economically and efficiently suit the needs and timing of actual customer commitments. For example, an initial phase could entail a load capacity of up to 14,000 tons, served by one seawater piping system combined with one chiller plant. A second phase could serve an aggregate of 20,000 tons, through the addition of a TES tank. A third phase could serve an aggregate of 33,700 tons, with the addition of the second seawater pipe and the second chiller plant. A fourth and final phase, adding the second TES tank, would achieve the total load capacity of 39,600 tons.

The system design has inherent, and important, flexibilities for planning and execution. Of course somewhat lower, or higher, ultimate system loads could be accommodated through the appropriate deployment of fewer, or more (or slightly smaller or larger) seawater pipes, chiller plants, and TES tanks. Final selection of the quantities, capacities, and timing will be appropriately dictated by the progress and prospects of DC system customer commitments.

Major Subsystems and Components

The SWAC/TES DC system design includes the following major subsystems:

- Seawater supply systems
- Centralized cooling systems
- Packaged chiller plants
- DC CHWS/R distribution systems
- Intra-system DC CHWS/R piping
- TES tanks
- TES tank-to-system interfaces
- Back-up power systems

Each of the subsystems is described in more detail below.

- Seawater supply systems

The system employs two independent HDPE (high-density polyethylene) seawater supply systems selected from the earlier designs that were specified to serve smaller individual DC networks in the downtown Honolulu waterfront and West Waikiki areas. These two systems draw seawater from the 1,600 ft (45 ºF) depth, and deliver it at 45.6 ºF to the on-shore centralized cooling stations. Further detail is provided in the earlier SWAC Report.

- Centralized cooling systems

The system employs two independent centralized cooling systems (pump and heat exchanger stations, employing titanium plate-and-frame type HXs) selected from the earlier designs that were specified to serve smaller individual DC networks in the downtown Honolulu waterfront and West Waikiki areas. These two systems are rated at 8,465 tons and 8,310 tons, respectively, delivering 46.5 ºF CHWS from the HXs. Further detail is provided in the earlier SWAC Report.

- Packaged chiller plants

Co-located with each of the centralized cooling systems, is a chiller plant that will operate in series with the SWAC HX to further lower the temperature of the chilled water delivered to the DC network. The chosen chiller plant design is a "packaged" approach employing pre-engineered skids. The packaged plants employ standard electric motor-driven centrifugal compression chillers (using refrigerant R-123) in a compact arrangement, along with the evaporators and condensers, chilled water pumps, condenser water pumps, and all associated motor starters, valves, instrumentation and controls. The skidded chiller plants are fully enclosed in environmentally-controlled insulated architectural enclosures, and are supplied on a turnkey design-build basis, guaranteed to meet specified performance. Similar packaged chiller plants have been used in dozens of large cooling system applications, including individual installations totaling up to 38,000 tons. They provide extremely small footprint requirements, as deemed important for this application. In addition, they provide a relatively rapid delivery schedule, high energy efficiency, and low capital cost. The chiller plants reduce the 46.5 ºF chilled water leaving the SWAC HXs to 39.0 ºF. The two packaged chiller plants have rated nominal cooling capacities of 5,520 tons and 5,420 tons, respectively. The still relatively cold (57 ºF) seawater leaving the SWAC HXs is used for refrigerant condensing, further saving space (eliminating the need for cooling towers) and further improving chiller energy efficiency. (Note: it is also possible that large DC customer chiller plants already in use could be utilized in lieu of the all or a portion of the new packaged chiller plant capacity. This could result in substantial capital cost savings for the development, even after paying a portion of the replacement cost for the existing chiller plant capacity. However, the present design and analysis assumes the more conservative approach of using all new chiller plant capacity.)

- DC CHWS/R distribution systems

The DC system's supply and return piping network is based partly on three independent distribution systems selected from the earlier designs that were specified to serve smaller individual DC networks in the downtown Honolulu waterfront, Kakaako, and West Waikiki areas. The new network is designed to deliver a nominal CHWS temperature of 39.5 ºF to the DC customers and return a nominal CHWR temperature of 58.0 ºF. Although each area will now be serving a somewhat larger total customer cooling load, piping diameters need not be increased, due to the larger DC system Delta T (now 18.5 ºF, up from the previous design of only 10.5 ºF). Nevertheless, due to the added customers, the DC network in each of the three regions is somewhat more extensive, with additional branch lines and additional customer interconnections.

- Intra-system DC CHWS/R piping

The integrated DC system comprises the three previously designed individual DC networks (in the waterfront, Kakaako, and West Waikiki areas), now somewhat expanded, plus the necessary intra-system supply and return piping. The intra-system piping involves two pairs of CHWS/R mains, one connecting the downtown waterfront area to the Kakaako area, and one connecting the Kakaako area to the Waikiki area, with each pair of mains being approximately one mile in length. The combined flow capacity in the two sets of intra-system mains is adequate to meet the average cooling loads of the Kakaako area DC customers on the peak design day. Again, the system is designed to employ nominal CHWS/R temperatures of 39.5/58.0 ºF.

- TES tanks

Two stratified chilled water Thermal Energy Storage (TES) tanks are employed. Each will be sited remotely from the central cooling systems and packaged chiller plants, and located strategically to act as "satellite" chiller plants during peak load periods when TES is being discharged. Likely locations for the tanks will be at inshore sites, where land is relatively less valuable and aesthetics are relatively less sensitive. Ideally, the tank sites will be along or nearby the intra-system piping mains, one on the West and one on the East of the Kakaako area. However, the tanks can be located virtually anywhere along, or within a reasonable distance of, any large CHWS/R piping in the DC network. As in the case of the DC piping network, the TES tanks are designed to operate at nominal CHWS/R temperatures of 39.5/58.0 ºF. Each of the TES tanks is designed to accommodate a maximum charge or discharge rate of 5,940 tons, with a rated TES capacity of 41,600 ton-hours per tank. Each tank will have a gross volume of approximately 3.82 million gallons. Tank dimensions can be varied to suit the final selected tank sites. However, representative dimensions for the tanks are 104 feet diameter by 60 feet shell height. Although large in size, the tank "footprint" is only 1.4 square feet per ton of discharge capacity, actually slightly less than what is typical for conventional chiller plants. Use of taller tanks would reduce the footprint further. The TES tanks are provided on a turnkey design-build basis, complete with foundation, leak-tight welded-steel tank per AWWA D100, interior and exterior paint, thermal insulation with vapor barrier and architectural jacket, internal flow diffusers for proper thermal stratification, and guarantees of thermal performance. Similar TES tanks have been employed in many dozens of other DC system developments, including individual tank sizes up to 160,000 ton-hours (17.6 million gallons).

- TES tank-to-system interfaces

Each TES tank is integrated with the DC piping network. The tanks are atmospheric pressure designs, with local piping hydrostatic pressure being equal to the head of water in the tank. To accommodate the higher pressures expected in the DC piping network, a set of TES pumps is employed to pump CHWS from the bottom of the tank during peak load, TES discharge periods. The same set of pumps is used to pump CHWR from the top of the tank during low-load, TES recharge periods. Six motor-operated valves per tank are alternately opened or closed to switch between the TES discharge and recharge operating modes. Flow from the network back to the tank (either CHWR to the tank top during peak load TES discharge periods, or CHWS to the tank bottom during low-load TES recharge periods) passes through a “back-pressure control valve” before re-entering the TES tank. The TES tank pumps are designed to provide variable flow.

- Back-up power systems

All pumps and chillers are provided with local engine-generators adequate to provide emergency back-up power. This allows the system to continue to be operated at full design cooling load, even in the event of a loss of electric power from the grid. (In practice, it could be possible to also design and use the engine-generators for electric power peak shaving during periods of high-demand high-cost electricity. This could result in significant reductions in operating cost. However, this enhancement has not been considered in the present design and economic analysis.)

<u>System Layout</u>

The actual system layout will be dictated by project specific issues. Notably, such issues include:

- Availability, cost and permitting of land for potential seawater piping landfall sites
- Availability, cost and permitting of land for potential SWAC HX and packaged chiller plant sites
- Availability, cost and permitting of land for potential TES tank sites
- Timing of the commitment of various CD customers

In general, it is anticipated that the seawater piping landfalls will be as anticipated in the earlier SWAC Report, one in the downtown Honolulu waterfront area near the downtown HECO power station and one in the West Waikiki area near the Fort De Russy Military Reservation. The central cooling systems (SWAC HX stations) and the association packaged chiller plants would be located near the two seawater piping landfalls. (Alternatively, The landfalls and central cooling stations could be re-located to be nearer to key DC customer facilities, if such facilities offered the use of existing chiller plants in lieu of the need for new packaged chiller plant capacity.) Seawater effluent lines will be routed to accommodate the most appropriate secondary uses, before returning to the sea. Most likely, the downtown effluent will be used for cooling at the HECO power station and the Waikiki effluent will be used for flushing of the Ala Wai.

The layout of the DC piping networks, comprising the CHWS/R main headers and branches, will be generally as anticipated in the earlier SWAC Report for the areas of the downtown Honolulu waterfront, Kakaako, and Waikiki. There will be somewhat more extensive branching and looping of the network, to suit additional customer loads. In addition, there will be the intra-system CHWS/R transmission mains interconnecting the three areas from West to East. Along these transmission mains, or somewhat further inland from them, will be the two TES tank sites.

As with most urban DC developments, the construction will proceed in phases. Initially there will be a conceptual design, with pipe routing and pipe sizes to accommodate the fully built-out mature system. However, actual routings, line sizes, and the timing of each phase will be somewhat of a moving target, being adjusted appropriately to suit actual and projected DC customer commitments.

Generally, the DC CHWS/R piping will be direct-buried beneath the city streets. However, where possible, the piping layout will make use of available alternative routing, such as within parking structures, through building basements (particularly in the case of large DC customer buildings), and through parkland. Such alternative routings have the potential for significant capital cost savings. However, the present design and analysis assumes the more conservative approach of all piping being under city streets.

<u>Construction Timetable</u>

For the SWAC/TES DC development, as for most urban DC developments serving a multitude of customers, the project will proceed in phases, dictated by the scale and timing of customer commitments.

The construction timetables listed in Table 3.1 (aggressive) and Table 3.2 (conservative) are hypothetical, but representative of other large DC developments. Actual timing will be subject to DC customer commitments. Some phases of construction may be combined with others, or even exchanged sequentially.

Note that the planning, marketing, customer contracting, engineering, permitting, and financing tasks are listed only for the initial project phases (1A and 1B). These activities will of course be on-going throughout the life of the development; however, for later phases, they will proceed concurrently with various construction activities from earlier phases, and are therefore not detailed in the timetable.

Table 3.1 – Representative Development/Construction Timetable (Aggressive)

Development Tasks	Duration (months)	Start Time (year, month)	End Time (year, month)
Project Initiation Activities			
Formation, seed funding, planning	3 mo	0 mo	3 mo
Marketing, conceptual designs, costing	6 mo	3 mo	9 mo
Customer contracting – phases 1A/B	6 mo	6 mo	1 yr
Final engineering, permitting – phases 1A/B	9 mo	9 mo	1 yr, 6 mo
Final financing – phases 1A/B	3 mo	1 yr, 3 mo	1 yr, 6 mo
Phase 1A (up to 5,500 tons)			
1st packaged chiller plant (downtown)	6 mo	1 yr, 6 mo	2 yr
DC distribution system	6 mo	1 yr, 6 mo	2 yr
Phase 1B (up to 14,000 tons)			
1st seawater supply system (downtown)	12 mo	1 yr, 6 mo	2 yr, 6 mo
1st centralized cooling system (downtown)	9 mo	1 yr, 9 mo	2 yr, 6 mo
DC distribution system	6 mo	2 yr	2 yr, 6 mo
Phase 1C (up to 19,900 tons)			
1st TES tank (downtown-Kakaako area)	12 mo	2 yr, 6 mo	3 yr, 6 mo
TES tank-to-system interfaces	9 mo	2 yr, 9 mo	3 yr, 6 mo
DC distribution system	6 mo	3 yr	3 yr, 6 mo
Phase 2A (up to 25,400 tons)			
2nd packaged chiller plant (Waikiki)	6 mo	3 yr, 6 mo	4 yr
DC distribution system	6 mo	3 yr, 6 mo	4 yr
Phase 2B (up to 33,700 tons)			
2nd seawater supply system (Waikiki)	12 mo	3 yr, 6 mo	4 yr, 6 mo
2nd centralized cooling system (Waikiki)	9 mo	3 yr, 9 mo	4 yr, 6 mo
DC distribution system	6 mo	4 yr	4 yr, 6 mo
Phase 2C (up to 39,600 tons)			
2nd TES tank (Kakaako-Waikiki area)	12 mo	4 yr, 6 mo	5 yr, 6 mo
TES tank-to-system interfaces	9 mo	4 yr, 9 mo	5 yr, 6 mo
DC distribution system	6 mo	5 yr	5 yr, 6 mo
Total Project Development	**66 mo**	**0 mo**	**5 yr, 6 mo**

Table 3.2 – Representative Development/Construction Timetable (Conservative)

Development Tasks	Duration (months)	Start Time (year, month)	End Time (year, month)
Project Initiation Activities			
Formation, seed funding, planning	3 mo	0 mo	3 mo
Marketing, conceptual designs, costing	12 mo	3 mo	1 yr, 3 mo
Customer contracting – phases 1A/B	12 mo	6 mo	1 yr, 6 mo
Final engineering, permitting – phases 1A/B	15 mo	1 yr, 3 mo	2 yr, 6 mo
Final financing – phases 1A/B	3 mo	2 yr, 3 mo	2 yr, 6 mo
Phase 1A (up to 5,500 tons)			
1st packaged chiller plant (downtown)	9 mo	2 yr, 6 mo	3 yr, 3 mo
DC distribution system	9 mo	2 yr, 6 mo	3 yr, 3 mo
Phase 1B (up to 14,000 tons)			
1st seawater supply system (downtown)	18 mo	2 yr, 6 mo	4 yr
1st centralized cooling system (downtown)	12 mo	3 yr	4 yr
DC distribution system	9 mo	3 yr, 3 mo	4 yr
Phase 1C (up to 19,900 tons)			
1st TES tank (downtown-Kakaako area)	12 mo	4 yr, 6 mo	5 yr, 6 mo
TES tank-to-system interfaces	10 mo	4 yr, 8 mo	5 yr, 6 mo
DC distribution system	8 mo	4 yr, 10 mo	5 yr, 6 mo
Phase 2A (up to 25,400 tons)			
2nd packaged chiller plant (Waikiki)	8 mo	5 yr, 10 mo	6 yr, 6 mo
DC distribution system	8 mo	5 yr, 10 mo	6 yr, 6 mo
Phase 2B (up to 33,700 tons)			
2nd seawater supply system (Waikiki)	15 mo	6 yr, 3 mo	7 yr, 6 mo
2nd centralized cooling system (Waikiki)	9 mo	6 yr, 9 mo	7 yr, 6 mo
DC distribution system	8 mo	6 yr, 10	7 yr, 6 mo
Phase 2C (up to 39,600 tons)			
2nd TES tank (Kakaako-Waikiki area)	12 mo	7 yr, 6 mo	8 yr, 6 mo
TES tank-to-system interfaces	10 mo	7 yr, 8 mo	8 yr, 6 mo
DC distribution system	7 mo	7 yr, 11 mo	8 yr, 6 mo
Total Project Development	**102 mo**	**0 mo**	**8 yr, 6 mo**

4.0 Economic Analyses

We have relied largely on the SWAC Report and the input of the DBEDT Project Manager regarding the seawater-related subsystem costs. We have relied on applicable experience and key industry contacts to develop the appropriate cost estimates for the TES and DC subsystems, as is routinely done in typical TES and DC activities. We have also relied, as appropriate, on experience in developing financial pro forma analyses for DC systems and DC/TES systems for DC system developers.

4.1 Determine the capital costs of SWAC/TES Hybrid systems and associated infrastructure development. A list of all major components and subsystems will be provided. Overall cost estimate will be accurate to ± 25%.

4.2 Determine the annual operating and maintain costs for each SWAC/TES Hybrid. Evaluate the benefits of variable speed pumping for chilled and seawater water supply and seawater disposal systems.

4.3 Determine comparative life-cycle costs of air conditioning (conventional vs. SWAC/TES Hybrid systems).

4.4 Determine annual revenue requirements for each SWAC/TES Hybrid system assuming linear scale-up to full operation in year 3.

4.5 Determine break-even revenue requirements for each SWAC/TES Hybrid system, and a projected rate of return, and identify other risks involved in such projects.

4.6 Identify, and prioritize, promising candidate SWAC/TES Hybrid systems for further technical and economic analysis.

Capital Cost Estimates

Capital costs have been individually estimated for all the major subsystems.

The budgetary planning estimate listed in Table 4.1 is judged to be conservative and to have an accuracy of approximately minus 25% / plus 15%.

A breakdown is presented in Table 4.2 to compare the installed capital costs for the three distinct types of cooling capacity employed in the hybrid SWAC-TES system design. It is noteworthy to consider the very wide range of installed unit capital costs, from over $3,000/ton for SWAC-related capacity, to $1,100/ton for the packaged chiller plant capacity, to under $500/ton for the stratified chilled water TES capacity. The net result for the full hybrid system is a unit capital cost of $1,730/ton, or barely over half the SWAC unit cost. It is also important to recognize that the actual costs are project-specific and could be significantly different for other SWAC projects in other locations with different bathymetry. Nevertheless, the data clearly illustrates the use of TES to dramatically reduce the high unit capital cost of non-TES SWAC systems. Furthermore, the remote siting of TES also contributes to reducing the DC system distribution piping costs.

Table 4.1 – Capital Cost Estimates

Subsystem	Capital Cost	Basis of Estimate
Seawater supply systems	$ 42,032,000	earlier SWAC Report estimate
Centralized cooling systems	$ 8,672,000	earlier SWAC Report estimate
Packaged chiller plants	$ 12,034,000	conservative budgetary quotation
DC CHWS/R distribution systems	$ 25,989,397	earlier and current estimates
Intra-system DC CHWS/R piping	$ 12,672,000	current estimate
TES tanks	$ 3,820,222	conservative budgetary quotation
TES tank-to-system interfaces	$ 1,910,111	current estimate
Back-up power systems	$ 3,037,300	earlier and current estimates
Contingency (at 20% of all other costs)	$ 22,033,406	conservative allowance
Total Capital Cost	**$132,200,436**	

Table 4.2 – Subsystem Unit Capital Cost Comparisons

Subsystem	Installed Capital Cost*	Cooling Capacity	Installed Unit Cost*
Seawater supply systems	$ 42,032,000		
Centralized cooling systems	$ 8,672,000		
Seawater-related chilled water capacity	$ 50,704,000	16,775 Tons	$3,023 / Ton
Packaged chiller plants	$ 12,034,000		
Conventional chiller capacity	$ 12,034,000	10,940 Tons	$1,100 / Ton
TES tanks	$ 3,820,222		
TES tank-to-system interfaces	$ 1,910,111		
TES-related chilled water capacity	$ 5,730,333	11,880 Tons	$ 482 / Ton
Total SWAC-TES cooling systems	**$ 68,468,333**	**39,595 Tons**	**$1,729 / Ton**

* excluding distribution system costs and contingencies

Annual Operating Cost Estimates

Annual operation and maintenance costs have been estimated.

An energy consumption rate of 0.5 kW/ton was assumed for the new packaged chiller plants. Actual consumption should be at least this low, in light of the planned use of cool seawater effluent for refrigerant condensing within the chiller plants. Additionally, unit energy costs have been conservatively estimated using an average electricity rate of $0.112 per kWh. Actual rates may be lower depending on available time-of-use rates for the chiller plant/TES installations. Energy costs were calculated to be approximately $5.65 million annually, initially, plus escalation over time.

Maintenance costs included an annual percentage of capital cost for each of the various subsystems and were estimated to be an additional $1.70 million annually. Again, this amount is adjusted for escalation over time.

Additionally, capital replacement of the seawater and chilled water pumps was conservatively estimated to occur after 10 years, representing an additional cost of $1.07 million.

Although operating personnel costs were not specifically estimated, this omission is considered conservative from the standpoint of comparisons to the base case of individual building self-cooling systems. Even with a highly-trained, well-staffed operating team for the DC system, it is common that there is a major operating cost savings for the DC system relative to the much larger amount of labor associated with dozens of individual building chiller operations.

<u>Variable Speed Pumping</u>

Regarding the use of variable speed pumps, there is the usual trade-off of higher initial capital investment versus higher energy efficiency and lower operating energy costs. In the case of the particular SWAC-TES DC system evaluated, there is a high level of modularity (and therefore turn-down capability) in terms of multiple seawater pumps and multiple chilled water pumps. Accordingly, there is not a particularly strong incentive to justify variable speed drives for these components. This result is further enforced by the use of TES. At any given time, a fixed selection of seawater and chilled water pumps can be operated at full capacity. Any fluctuations in DC system cooling demand above or below the pumping system capacity is accommodated by the charging or discharging of the TES tanks. Increasing or reducing pump capacity in incremental amounts equal to one entire pump at a time is therefore quite appropriate.

Potential variable flow control of seawater effluent used for auxiliary purposes can only be evaluated once the actual auxiliary uses are better defined. However, it is anticipated that constant flow seawater pumps (potentially sequenced in increments as noted above) will be suitable for most auxiliary effluent applications.

However, the TES tank pumps should be equipped with variable speed drives, as the flow into or out of the tanks will vary continuously over a wide range, both during charging and discharging operations. The use of variable speed tank pumps will optimize operating costs, but equally importantly, will enhance control and help to maintain maximum Delta T in the chilled water system and maximum capacity in the TES tanks.

<u>Life-Cycle Cost Comparisons</u>

Life-cycle costs were developed for the SWAC-TES hybrid DC system using the same methodology and consistent assumptions as applied in the earlier SWAC Report for conventional in-building cooling systems and for the non-TES SWAC DC systems.

Direct comparisons of life-cycle costs show the SWAC-TES hybrid DC system to be a significant improvement relative to non-TES SWAC DC systems, which in the earlier SWAC

Report were projected often to be quite advantageous relative to conventional in-building self-cooling systems.

Table 4.3 – Life-Cycle Cost Comparisons

Air-Conditioning District	Levelized Cost Over Book Life ($ per ton-hour) non-SWAC	SWAC DC	SWAC-TES DC
Downtown Honolulu Waterfront	0.1532	0.1223	
Kakaako	0.1535	0.1323	
West Waikiki	0.1532	0.1218	
Combined Waterfront-Kakaako-Waikiki			0.1102
East Waikiki with U of Hawaii at Manoa	0.1535	0.2413	0.2130

As illustrated in Table 4.3, the use of the SWAC-TES hybrid DC systems reduce life-cycle cooling costs by approximately 12% relative to the non-TES SWAC DC systems. In the high cooling density areas of Oahu's South Shore from the downtown waterfront through Waikiki), the SWAC-TES DC system life cycle costs represent a savings of nearly 28% when compared to individual in-building chiller systems.

Annual Revenue Requirements, Return and Risks

The issues of revenue requirements and return on investment are of course interrelated. The acceptable minimum rate of return will vary significantly depending on the investor or system owner. Typical private sector DC developers expect a mid-teens annual percentage rate return. Some large public sector infrastructure projects are required merely to break-even (examples: many toll-roads and, for many decades, the Panama Canal). It is even conceivable that the seawater intake infrastructure portion of the system could be a public sector development that, as an example, would sell water to users at a break-even cost; and that the primary customer would be a private sector developer (or perhaps a public-private partnership) that would operate the DC system for a profit. This is somewhat analogous to other DC developments that purchase steam from municipal waste-to-energy plants, and then utilize the steam to produce chilled water.

As with any large project and any financial investment, risks must also be considered. The risks comprise both technical and financial issues.

At this point, the technical risks of the proposed SWAC-TES DC systems are judged to be quite readily managed. This is due to the significant existing successful experience in individually executing all the major elements of the proposed development, including deep water piping, heat exchange/pumping stations, packaged chiller plants, DC piping networks, and large stratified chilled water TES tanks. The combination of these subsystems into an integrated system is not considered a technical challenge.

The financial risks are the more significant concern. However, the potentially very large risks associated with the full capital investment are substantially mitigated through the planned phased approach to the development. As described earlier, the 40,000 ton, $132 million SWAC DC development is projected to be executed in six distinct phases, with each phase being less than 10,000 tons. Accordingly, the capital commitment for any one specific phase is a small fraction of the total project cost. Even more importantly, it is contemplated that major capital commitments will not be undertaken without firm contracts or letters-of-intent from customers associated with each major phase of the development. In this manner, financial risks are also deemed to be quite acceptable.

The most serious risk (to potential developers, and thus to the successful launch of a SWAC DC system) may actually be the relatively smaller, yet still significant, financial investment associated with the initial development effort. This effort is a combination of planning, marketing, design, permitting, financing, and sales activities. It represents a substantial commitment of time, effort and capital to reach the point of achieving the “critical mass” of customer commitments necessary to embark on the first phase of detailed engineering, permitting and construction. The investment in this early development effort will be considered “at risk” by developers. For this reason, the development process would benefit from the formation of a public-private partnership and access to “seed” funding, as described in more detail in Section 5 of this report.

Candidates for Further Analysis

In addition to the SWAC system presented and analyzed above, there are additional promising candidates that justify further analysis, with the incorporation of TES. These potential SWAC DC systems include the following:

1. East Waikiki, potentially including the University of Hawaii at Manoa – The East Waikiki area could easily and economically be integrated with the expanding South Shore SWAC DC system. Although the distance to the UHM campus represents a high capital cost for on-shore CHW piping, the piping size and cost can be substantially reduced through the use of a chilled water TES tank located at the campus.
2. The military facilities in and around the Pearl Harbor Naval Shipyard – Although the earlier SWAC report found this area to be somewhat less attractive economically than the downtown, Kakaako and Waikiki areas, the use of TES will enhance the economics. Other very promising characteristics include: 1) a very large magnitude of cooling loads controlled by very few facility owners, 2) an impending need to modernize aging chilling infrastructure and a desire to add cooling to other facilities, 3) institutional program goals to reduce energy use and energy costs, and 4) a long-term planning horizon.
3. The West Beach area of Oahu – This area represents a potential for new commercial real-estate development, and thus provides a clear capital cost offset in avoided in-building chiller plants. Again, relatively few decision-makers will control a large amount of cooling loads. Furthermore, the deployment of a SWAC-based cooling infrastructure would be an aid to the successful economic development of the area. Finally, as the West coast of Oahu has close economical access to 3,300 ft deep, 40 ºF seawater, the need for supplementary chiller plants is mitigated; the resulting system design would be simpler, less costly, and even more energy efficient than using the South Shore system design.
4. Kaneohe Marine Corps Base Hawaii – Although the earlier SWAC report projected less than ideal economics, the use of TES could help improve SWAC economics to an

essentially break-even condition when compared with conventional cooling systems. The facility has the advantage of a single owner/decision-maker and institutional goals to reduce energy use.

5. Future Combustion Turbine Power Plants – It is anticipated that in the near future, on-going peak electric demand growth in the Hawaiian Islands will be met largely by the construction of combustion turbine (CT) power plants. However, CT output is highly dependent on inlet air temperature. A SWAC system, optimally integrated with TES, could be used to chill the CT inlet air to 50 or 45 ºF, increasing CT power output by approximately 25% and improving fuel consumption by approximately 5%. Of equal importance, the enhanced output would slow the need for new CT capacity by 20% (e.g. a conventional CT installation of five turbines would be reduced to only four of those same turbines with inlet cooling). Depending on the location of the new CT power plants, the SWAC-TES systems could be solely dedicated to CT inlet cooling or could be used in combination with more extensive SWAC DC systems. Also, the effluent will likely have substantial value for auxiliary cooling uses in the power plants. A final benefit is that the CT inlet air heat exchangers (cooling coils through which the cold seawater or CHW will flow) will generate substantial amounts of fresh water via condensation on the exterior of the coils; this water can be collected and used in the power plants or elsewhere.
6. The NELHA facility area at Kailua-Kona, The Big Island – The Natural Energy Laboratory of Hawaii Authority (NELHA), located at the Kona airport, has already deployed and operates several deep seawater intake pipelines, used for research purposes, primarily in aquaculture and agriculture. The newest and largest of the intakes has the capability to deliver 39 ºF seawater at rates of up to 27,000 gpm. Assuming a 15 ºF Delta T, the intake could provide approximately 17,000 tons of cooling (and perhaps 24,000 tons or more when integrated with TES). The effluent temp (54 ºF) would still be colder than needed by most NELHA research tenants. Based on the current NELHA cooling water tariffs, a cooling user could purchase deep cooling water at a rate of under $0.01/ton-hr. If and when any large, or even moderate size, cooling users locate to the nearby area, it should be extremely economical to develop a DC system to integrate with the existing seawater intake system.
7. Other Neighbor Island developments – TES is expected to enhance the economics of SWAC systems generally. Accordingly, when considering any other potential applications throughout the islands, TES should be included in the design concept and the economic evaluation. The most attractive candidates will exhibit one or more of the following characteristics: relatively short access to deep water, large coastal cooling loads, high cooling load density, relatively few decision-makers controlling a large percentage of the loads, new construction or facility expansion or a need for existing chiller replacement, and nearby auxiliary uses for the effluent.

5.0 Marketing Plan to Allow Private Sector Development of One, or More, of These SWAC/TES Hybrid Systems in Hawaii

We have relied on past experience in developing successful DC marketing plans, as used in the development of actual new commercial DC systems.

The Marketing Plan for the SWAC DC systems should proceed logically from the Vision, Goals, Targeted Customers, and Strategy that are the basis for the SWAC DC development.

<u>Vision</u>

The Vision is literally a "Cool Hawai'i" achieved via use of deep ocean water cooling, a renewable energy resource. This will result from creation of a mechanism for initiating successful commercial implementation of sustainable large-scale SWAC DC systems in Hawaii, with major resultant benefits to energy efficiency, the environment, and the economy.

<u>Goals</u>

A 40,000 ton SWAC DC development on the South Shore of Oahu will provide the following benefits:

- Efficient, renewable, and reliable cooling service for 16 million sq ft of facilities
- Approximately 75% savings in electrical energy for cooling (150 million kWh/yr)
- Comparable reductions in CO_2, refrigerants, and air & water pollutants
- 30 megawatt (approximately 2%) reduction in Hawaii's total peak electric power demand
- Avoidance of 336,000 barrels of imported oil equivalent per year
- A projected 10 to 20% reduction in life-cycle cooling cost for customers
- A projected 15% Return-on-Equity for equity investors
- Over $130 million in construction project spending
- Local tax revenues and potential franchise fees
- Numerous local auxiliary uses of the cool effluent seawater

Such a development will be implemented in several phases, with an initial phase likely to serve 8,000 to 14,000 tons of peak cooling loads. Thus the initial phase would achieve benefits that are approximately 20 to 35% of those noted above for a 40,000 ton development.

Ultimately, it is envisioned that the Honolulu-Kakaako-Waikiki SWAC DC development will grow well beyond even 40,000 tons, perhaps in time being twice as large. Also, it is envisioned that other significant SWAC DC systems will develop serving other areas on Oahu and on the neighbor islands.

<u>Targeted Customer Sectors</u>

The primary targeted building sectors are commercial and institutional:

- Commercial building sector – including hotel, office, retail, and resort facilities

- Institutional building sector – including military, educational, healthcare, and other governmental facilities (e.g. city, county, state and federal office and administration buildings, airports, convention centers, sports/entertainment complexes, and museums)

Secondary targeted building sectors are industrial and residential:

- Industrial building sector – including new and future electric power generation plants, process cooling and refrigeration, and heat rejection elements of various industries
- Residential building sector – including apartment buildings and condominium developments

Strategy

A successful SWAC DC development will result from a largely two-pronged approach, aimed firstly at direct DC customer marketing/sales activities and secondly at building political and community support. There are two key, independent messages to be conveyed.

The primary marketing message is targeted to prospective DC customers and involves the economic and outsourcing benefits of the DC project to those customers, on a specific individual basis. Specific individual prospective customers will value various issues differently. The sure means to achieving widespread DC customer commitments is by demonstrating either significant (e.g. 10 to 20%) reductions in life-cycle DC costs versus self-cooling costs, or comparable cooling costs coupled with significant ancillary benefits valued by that customer. As already projected, life cycle cooling cost savings should be demonstrable to prospective customers.

A very critical and complementary secondary message is also conveyed to the prospective customers but is aimed more specifically at the government, the affected community, the public at large, and other interested groups (local media, environmentalists, business associations, engineers, etc.). This second message involves the environmental benefits and the economic development benefits to the community.

Fit with Local Priorities

The implementation of SWAC DC systems in Hawaii will directly address a myriad of local priorities, in quantitatively significant ways. These local priorities, already explicitly identified, include the following.

The City and County of Honolulu's Mayor has adopted a goal of reducing electrical demand in City facilities by 50% by the year 2010. Furthermore, the State of Hawaii's Governor has pledged to:

- Achieve 20% renewable energy use by 2020,
- Design all State projects and buildings to use renewable energy to the maximum extent possible,
- Lobby for federal funds to support Hawaii's development of alternative energy sources,
- Eliminate excise and fuel taxes on renewable fuels, and
- Extend tax credits for energy conservation installations.

The State of Hawaii, under Act 77, Part II (passed by the 2002 Hawaii State Legislature), is required to reduce energy use in its facilities by 30% by 2012, and use renewable energy for 20% of the remainder. The 2003 legislature is considering $100 million in bonds to fund implementation of Act 77. Federal agencies in Hawaii are under a similar mandate (EO13123).

Large cooling users (both private and public) pay premium prices for electricity for air-conditioning, and are subject to periodic cost increases related to electricity and fuel costs.

Commercial property and tourism resort development will benefit from the implementation of cooling infrastructure.

Military facilities in the Pearl Harbor area are largely dependent on aging inefficient energy and cooling infrastructure.

SWAC technology represents a potential export industry for Hawaii.

Initial Focus – The Public Private Partnership (PPP) Approach

As has been the case in many other DC developments, the successful implementation of the SWAC DC development can be greatly streamlined through the use of a Public Private Partnership (PPP) approach. Technical and economic feasibility of the SWAC concept have already been demonstrated through various studies conducted by or for the State and the U.S. DOE. A subsequent focus on identifying and securing public sector participation for a partnership, is deemed to be the crucial next step in the timely successful realization of the "Cool Hawai'i" Vision.

Potential "Partners" and Their Proposed Responsibilities

The potential public sector partners include one or more entities from among the following:

- Federal Government – potentially responsible for seed funding, supportive investment tax credits, accelerated depreciation rates, energy production (or avoidance) credits, expediting of various permit processes, and/or participation as a cooling customer at various federal (office, military and other) facilities
- State Government – potentially responsible for seed funding, independent confirmation of energy and environmental benefits, supportive electric demand management incentives, Hawaii Energy Conservation Income Tax Credit, expediting of various permit processes, public awareness and public education, and/or participation as a cooling customer at various State (office, university and other) facilities
- Local Government – potentially responsible for seed funding, low cost or tax exempt financing, supportive property tax rates, rights-of-way for chilled water distribution piping, expediting of various permit processes, public awareness and community relations, and/or participation as a cooling customer at various local (office and other) facilities

Subsequent potential partners and/or stakeholders include a wide variety of pother groups, each of which should be addressed within the final Marketing Plan. They include:

- Environmental Groups
- Local Chambers of Commerce and Business or Community Groups
- Local Property or Resort Developers
- Individual Large Cooling Customers
- Auxiliary Service Users
- Local Electric Utilities
- Project Consultants, Equipment Suppliers and Contractors
- Private Investors

How Development Activities May Be Supported

Ultimately, the technology, and the activities of the partnership will be self-sustaining through the revenues received from its cooling customers. The financial structure of the commercial developments may also be supplemented by economically justified incentives for renewable energy use, energy conservation, and/or electric demand management.

To cover an initial period of 18 to 30 months, the partnership will provide or obtain financial "seed" funding to support the essential business development efforts to:

- create a detailed business model for the SWAC system(s),
- engage and educate local communities, governments, and prospective customers regarding the specific benefits,
- identify and select appropriate project equity and debt financing sources (as well as potential incentive contributions),
- develop and implement marketing plans,
- negotiate necessary agreements with customers, developers, and local authorities, and
- obtain necessary approvals from local, State and Federal jurisdictions.

In spite of the attractive life-cycle economics projected for the SWAC developments, the initial capital investments are very high. In order to overcome the expected reluctance of the conservative private investment community, it is deemed important to have public support, embodied through certain commitments that can be provided through the PPP. Such commitments can be made by Federal, State and/or local authorities and include:

- financial seed funding for the near-term development activities listed above,
- use of life-cycle cost analysis for decision-making on their own facility cooling investments,
- agreement to use SWAC in appropriate government owned or controlled facilities,
- assistance in promoting public awareness and understanding of the benefits,
- assistance in securing justified incentives, such as one or more of the following: 1) low cost or tax exempt financing, 2) federal investment tax credits, 3) accelerated depreciation rates, 4) electric demand management incentives, 5) Hawaii Energy Conservation Income Tax Credit, 6) energy production (or avoidance) incentives, and 7) reduced property tax rates (especially related to offshore piping),
- reasonable access to land and rights-of-way for seawater intake pipe landfalls, pumping and heat exchange stations, chilled water distribution piping networks, and complementary Thermal Energy Storage (TES) and chiller plant sites, and

- assistance in expediting the process of permit reviews and approvals.

In short, the local, State and Federal government authorities can participate in the PPP in many ways and to varying degrees of their choosing. Such participation can be relatively limited and take the approach of a silent but supportive partner. Or participation can be more direct and involve the government acting as a system customer and/or as a system developer and equity investor. Regardless of the level and type of public support, some amount of public commitment is judged to be essential to the successful launch of this beneficial endeavor to “Cool Hawai’i.”

Development Time Frame / Schedule

Past activities, including technical and economic feasibility studies and sensitivity analyses, have built the necessary foundation for the embarking on the commercial realization of Cool Hawai’i.

Once a key public partner joins the Partnership with basic seed funding, the critical business development steps can proceed. A period of 18 to 30 months follows to accomplish the steps necessary to achieve a major project implementation release. From that point forward, such a system (8,000 to 14,000 tons of SWAC in an initial phase) will be self-funding.

Following the commitment to proceed with a SWAC project, the steps of detailed system engineering, construction and commissioning will take an additional 12 to 15 months to place the SWAC DC system in operation. Customer cooling agreements are anticipated to cover an initial term of 20 years, while the SWAC system’s technical and economic life is expected to extend over many decades.

It is anticipated that the Partnership may and should remain active for a minimum period of 36 to 48 months, in order to champion and support the development of: 1) follow-on phases to the initial SWAC system, 2) subsequent independent SWAC systems in Hawaii, and 3) a vehicle to export this Hawaiian developed technology to other appropriate locales. Of course, the Partnership may continue indefinitely, as is the case with some DC systems in which the public sector partner maintains an equity position.

As actual SWAC projects become active, the original Partnership may evolve into, or spin-off, related Partnerships that will build, own, and/or operate individual SWAC systems. Within the next 10 years, a total of 50,000 to 100,000 tons of local SWAC systems are envisioned, thus creating a truly Cool Hawai’i.

The Marketing Plan Activities

The detailed elements of a representative working Marketing Plan are presented in Table 5.1, based on similar plans used successfully in other DC developments.

Prospective customers should be targeted in a priority schedule that is determined by specific characteristics, such as the following:

- Capacity (prospects controlling one or more facilities with large aggregate cooling loads)
- Location (prospects near existing or planned DC lines, and/or near other large prospects)

- Existing cooling situation (prospects in need of new cooling capacity, or candidates to sell useful existing chiller plant capacity to the DC operator)
- Any new construction or facilities planning major expansions
- Government facilities under mandate to improve energy efficiency
- Facilities requiring high reliability in their cooling supply
- Interest Level (prospects with a marked inclination to consider SWAC DC, for whatever reason)
- Properties whose owners already utilize DC service in other cities

Table 5.1 – Representative DC Marketing Plan Activities

Activity Categories	Examples of Specific Activities
Unique Business Identity	Logo, Business Cards, Letterhead, Telephone, Facsimile, Office Address , P.O. Box Number, and Website
Brochure (full color glossy)	Focused on the SWAC DC project, benefits, and the PPP
Flyers (1-page glossies)	SWAC DC Benefits Project Fact Sheet Partnership Qualifications and Experience Individual Customer Profiles (initially from other DC systems) Glossy Folder (to organize the various flyers, etc.)
Newsletter (4 issues/yr)	Features: SWAC and DC technologies and benefits, the PPP, the specific SWAC DC project, environmental focus, econ development focus, customer commitment updates, in-service milestones and results, benefits at full build-out
Press Releases	target: local media, gov't officials, key prospects, related org's topics: PPP formation, project announcements (each phase), customer commitments, in-service milestones (each phase)
Articles	target: local newspapers and magazines topics: the SWAC DC concept, past experience, the project, environmental benefits, economic development benefits
Print Advertising	as deemed appropriate, e.g. to encourage editorial coverage
Marketing Novelties	pens, hats, beverage coolers, mouse pads, etc.
Plant and Customer Tours	first to NELHA; later to SWAC DC plants and customers
Special Events	Receptions, Ceremonies, Seminars
Government Relations	City and County of Honolulu State of Hawaii U.S. (DOD, DOE, EPA, GSA, etc.)
Community Relations	Business Associations, Community and Environmental Groups
Interact w/ Other Organizations	AIA, ASHRAE, BOMA, Chamber of Commerce, Hawaiian Electric Company
Customer Sales Tools	Introductory PowerPoint presentations and handouts Questionnaire / Data Solicitation Forms Standard LOI (Letter-of-Intent) Standard Proposal Standard DC Service Agreement (Customer Contract)

6.0 Possible Financing Mechanisms for SWAC/TES Hybrid Systems

We have relied on past experience and industry contacts in identifying and evaluating potential financing mechanisms, as employed in private, public, and public-private partnership (PPP) DC developments. Potential financing mechanisms include equity investments and loans, as well as tax-exempt bonds, energy efficiency grants, demand-side management incentives, and performance contracting.

It is meaningful to note that a number of current circumstances support the prospects for obtaining project financing. These include:

- The SWAC feasibility analysis (Oct 2002),
- Previous and on-going, DC market analysis and marketing in the Honolulu area,
- Existing technical precedents for both DC systems and for Deep Water Source DC systems, and
- Government (State and Federal) mandates and support to encourage SWAC DC development.

However, financial investment markets are generally "skittish" at present. In a recent US DOE sponsored poll of universities, related to Combined Heat & Power developments, major barriers were identified and ranked. From the institutional perspective, access to capital was identified as their number one concern:

It is important to recognize that DC represents different things to different people. Some of the most relevant issues (and the associated stakeholders with specific interests in those issues) include:

- energy costs and real estate issues (chilled water users),
- economic development (local governments),
- peak demand management (the local electric utility), and
- financial risk/reward (investors, both active and passive).

Although listed as distinct stakeholders in the list above, the chilled water users, the local government, and the electric utility are all sometimes also direct investors (owners, or partners in ownership) in DC developments. Examples of Public-Private Partnership (PPP's) mechanisms include BOT (build-operate-transfer), BTO (build-transfer-operate), and perhaps most appropriately, BOO (build-own-operate). There are many precedents for the PPP approach, including water and wastewater treatment systems, infrastructure development (e.g. transportation), and indeed, DC systems. Just a few representative examples of DC PPP's include the following:

- Orlando, FL – In this case, the DC development is a 50/50 joint venture between the local, municipally-owned electric utility and a private District Energy developer-owner-operator.
- St. Paul, MN – In this case, the DC development is a not-for-profit cooperative, in which the DC customers (including the City government, the State government, and various private customers) jointly own the DC system.
- Kansas City, MO – In this case, the DC system is 100% financed, owned and operated by a private District Energy developer; however, all the initial "anchor" customers that

represented the "critical mass" to proceed with the development were public sector facilities (comprising the Federal, County, and City government buildings in the downtown area).

A successful Finance Plan must exhibit certain characteristics, notably:

1. It must be credible to DC investors.
2. It must strike a balance between cost of capital and covenants.
3. It must ensure a long-term funding commitment.
4. It must be able to result in a "close".

The Capital Markets Equity Pool includes utilities, institutional, and investment funds. The Capital Markets Debt Pool includes institutional, commercial, and municipal sources. A potential resource would be the participation of a PPP in the development. The PPP approach can often provide:

- a local ownership component to complement mainland DC experience,
- improved access to land and rights-of-way, and
- an accelerated schedule for logistical issues.

It is important to manage investor expectations and risk:

- DC developments should not be targeting high-risk venture capital with high potential gains. Realistic and attractive returns for typical DC developments are in the low teens.
- Competitive debt rates are necessary. This is especially true for the SWAC DC systems which are particularly capital intensive, even compared to conventional DC developments which are themselves quite capital intensive.
- The PPP approach often helps in attracting and satisfying guarantors.
- Coverage ratios should be attainable (and are often managed by the phasing of development and investments, to the extent practical).

Lessons learned from past experiences with DC developments have demonstrated that there are certain necessities for successful financing. These necessities include: pre-sold long-term customer contracts, solid contract terms, long-term credit worthiness of customers, and market sustainability. Also very important are DC management experience, a strong DC marketing commitment, and proven success stories of successful DC development and operation serving similar customer facilities.

Recommended next steps for a Finance Plan for Hawaii SWAC systems include:

1. Developing a "qualifying prospectus",
2. creating an appropriate PPP,
3. confirming the financial market feasibility, and
4. when warranted, producing an offering memorandum.

A precursor to the *pro forma* financial analysis includes defining:

- what the market will bear, through a price point analysis that reflects customer perspectives (and where necessary, an educational process to realistically shape customer perspectives),
- individually differentiated and aggregated customer load profiles,

- a chilled water rate structure, generally incorporating: 1) a capacity charge component based on maximum contract tons (and set to recover all fixed costs plus profit), 2) a consumption charge component based on monthly ton-hour utilization (and set to recover all marginal production costs), and 3) appropriate annual escalation indices, and
- a real-estate comparison of DC versus self-cooling options (preferably on a $ per sq ft basis).

A recent Case Study of a Downtown Honolulu SWAC DC development (Phase 1) was completed, with the following assumptions:

- 8,465 Tons of customers (40% market penetration) over 3 years
- $42 million in capital costs
- A composite debt rate of 6.25%
- An equity amount equal to 30% of capital expended
- Minimum Return on Equity (ROE) of 13%
- Minimum Debt Coverage Ratio (free cash flow over debt service or EBITDA/P&I) of 1.5

Preliminary *pro forma* results through 3 phases of that Case Study were developed and, as illustrated in Table 6.1, appear promising.

Table 6.1 – Recent Case Study for Downtown Honolulu SWAC DC

	Phase 1	Phase 2	Phase 3
Percent market share*	40%	60%**	80%
Customer Load (Tons)	8,465	12,700	16,930
CapEx (cumulative total)	$42 million	$48 million	$50 million
ROE	16.0%	19.0%	24.5%
Debt Coverage Ratio	1.5	2.0	3.0

* Based only on the large potential customers in Honolulu.
** The DC system in St. Paul, MN achieved 60 to 65% market share within 10 years.

The Waikiki and Kakaako developments could be expected individually to produce comparable results. The proposed development approach of integrating the three systems into a combined DC network, with low cost TES as an enhancement, produces even better projected results, as previously discussed.

Other issues (also not yet factored into the *pro forma* above), could generate very significant further enhancements. Such enhancements include:

- investment tax credits,
- Act 221 tax credits,
- TES tax credits,
- bonus depreciation schedules,
- utility rebates (justifiable in amounts potentially up to $650 per avoided peak kW), and
- federal energy production incentives (potentially $0.015 or even $0.045 per kWh of avoided energy use).

Due to their potential significance to the project's bottom line, and thus to the overall financing of the development, it is recommended that mechanisms to capture these enhancements be explored further. They should be investigated in enough detail to define which may be realistic, to quantify the value to be gained, and to identify the necessary steps to ensure that the value is indeed captured.

7.0 The "Innovative Energy Systems Workshop" Held in Honolulu, Hawaii (March 2003)

Note: The Workshop also covered energy storage systems, district cooling systems, and waste heat recovery. Selected invited speakers presented information on each of these topics. This Workshop brought together mainland and international experts in energy storage systems, district cooling systems, and waste heat recovery with local experts in SWAC systems, in order to help commercialize such systems in Hawaii.

Participants included local building owners and operators, designers, engineers, equipment dealers, financial institutions, utilities, governments, universities, and interested members of the general public. Defined activities included the following.

7.1 Present the preliminary results of this project to Workshop participants.

7.2 Serve as a panel member and topic expert during this Workshop.

7.3 Collect and collate any information relating to District Cooling, TES, and SWAC/TES Hybrid systems presented at this Workshop.

7.4 Summarize the information obtained in item 7.3, above, and incorporate this summary into the final project report.

We also dedicated additional time in Honolulu immediately before and after the Workshop, to interact with the DBEDT Project Manager and to gain first-hand observations of the key candidates for SWAC/TES system development.

A complete detailed report of all SWAC, District Cooling, and TES related elements of the Workshop is provided in the Appendices of this report.

8.0 Conclusions and Recommendations

Conclusions

Some significant conclusions are drawn from this study:

The findings of the earlier SWAC report ("Sea Water District Cooling Feasibility Analysis for the State of Hawaii"), dated October 2002, were reviewed. The design, economic, and operational assumptions related to the District Cooling (DC) aspects were verified to be appropriate and somewhat conservative.

Generally, SWAC system economics will be significantly improved through the use of Thermal Energy Storage (TES). TES leverages the capacity of the typically high capital cost seawater piping system, through the addition of a relatively inexpensive TES element that can generally add 33 to 50% to the available peak cooling load capacity of the integrated SWAC-TES system.

A literature search documented the already extensive successful use of various types of TES, including ice, chilled water (CHW) and low temperature fluid (LTF) TES, in DC applications around the world.

All three TES technology types could be employed effectively in combination with SWAC DC systems. However, due to both technical and economic characteristics inherent to these technologies, CHW TES will generally be the most advantageous choice for large SWAC DC applications. The primary reasons are economy-of-scale, compatibility for direct recharge using available seawater temperatures, and the ability for siting remotely from (or even without) chiller plants. Each potential SWAC application should be evaluated carefully to determine the optimum choice and configuration of TES.

Potentially the largest the most promising SWAC system for Hawaii is an integrated DC system serving the combined areas of the downtown Honolulu waterfront, Kakaako, and Waikiki. Such a system can serve 40,000 tons of customer cooling load over several years of growth in phases (and potentially even larger peak loads eventually). The conceptual approach employs multiple seawater intake pipelines and seawater-to-CHW heat exchangers, multiple packaged chiller plants to supplement cooling capacity and reduce the available CHW supply temperature to a more desirable level, and multiple stratified CHW TES tanks strategically located along the DC system's CHW distribution network. In this manner, two high-cost seawater intake systems totaling 17,000 tons of capacity are combined with 11,000 tons of low-cost packaged chiller plants plus 83,000 ton-hours of even lower cost TES, to meet peak loads of 40,000 tons.

The chosen concept provides essential aspects that will enhance the economics, operating flexibility, reliability, and even the marketability of the SWAC DC system. These elements include:

- the ability to execute the development in discrete phases,
- the use of multiple elements of cooling capacity in which any one element represents a relatively small fraction of the total system capacity,
- maximized utilization of the installed seawater intake capacity,

- a relatively large DC system supply-to-return temperature differential, and
- the use of TES to maximize not only peak cooling capacity but also distribution network capacity.

An economic evaluation, employing methodology and assumptions consistent with those used for the earlier SWAC Report, demonstrated significant improvements through the use of TES. The downtown Honolulu waterfront-Kakaako-Waikiki SWAC-TES DC system was found to have a 12% lower total life cycle cost of cooling than was the case for the earlier non-TES SWAC DC systems individually evaluated for those same three areas, and 28% lower than the cost of conventional in-building chiller systems. Similar life cycle cooling cost reductions (10 to 15%) can be expected from integrating TES with SWAC DC designs serving other areas.

The 40,000 ton SWAC DC development on the South Shore of Oahu will provide the following benefits:

- Efficient, renewable, and reliable cooling service for 16 million sq ft of facilities
- Approximately 75% savings in electrical energy for cooling (150 million kWh/yr)
- Comparable reductions in CO_2, refrigerants, and air & water pollutants
- 30 megawatt (approximately 2%) reduction in Hawaii's total peak electric power demand
- Avoidance of 336,000 barrels of imported oil equivalent per year
- A projected 10 to 20% reduction in life-cycle cooling cost for customers
- A projected 15% Return-on-Equity for equity investors
- Over $130 million in construction project spending
- Local tax revenues and potential franchise fees
- Numerous local auxiliary uses of the cool effluent seawater.

Other promising candidate SWAC DC systems that would benefit from TES include:

- the East Waikiki-University of Hawaii at Manoa area,
- the Pearl Harbor Naval Shipyard area,
- the Oahu West Beach area,
- the Kaneohe Marine Corps Base,
- future combustion turbine power plant installations (for which SWAC would be used for inlet air cooling),
- the NELHA area in Kailua-Kona on the Big Island (which could employ an existing deep seawater intake), and
- other select applications on the neighbor islands.

The challenges of marketing and financing the SWAC DC developments in Hawaii are significant. However, they are not different in kind, only somewhat in degree, from the challenges that are frequently addressed and overcome in many successful DC developments.

The creation of a public-private partnership (PPP), along one of many possible models that have been employed successfully in other infrastructure developments including DC, would aid significantly in generating the necessary initial momentum for commercial realization of SWAC DC systems in Hawaii.

The presentations, panel discussions, and general attendee participation at the "Innovative Energy Systems Workshop" generated the following consensus:

- Technology developments in the areas of deep seawater intake systems, DC and TES are quite mature at this point. Demonstrations, and in many cases successful commercial installations, underscore the readiness for more widespread application.
- The cold water (deep ocean) resource is a unique advantage and opportunity throughout Hawaii.
- Hawaii offers numerous potentially beneficial uses of that resource.
- Benefits will accrue to users, developers, the community, the State, the environment, and others.
- Economic feasibility has now been demonstrated for many potential applications in Hawaii.
- Immediate effort should be focused on moving the technologies into commercial realization.
- A key element of successful commercial development could be the identification and formation of an appropriate Public-Private Partnership, along the models employed in other successful developments.

<u>Recommendations</u>

The following recommended actions represent steps that should further the commercialization of SWAC DC systems in Hawaii and thus realize the significant energy, environmental and economic benefits of deployment of this technology.

1. TES should be integrated with SWAC DC system designs to enhance overall economics. Not only will this improve project economics for the developers and the customers, but more importantly, the incremental improvement from TES (perhaps a 10% or greater reduction in life cycle cooling costs) may represent the difference between success and failure in the actual realization of specific SWAC projects.

    - The primary focus when integrating TES with SWAC DC systems should be to minimize capital cost per peak ton of installed system cooling capacity, as it is capital cost that drives the *pro forma* financial analyses of SWAC systems. Operating energy costs are inherently low with SWAC systems. Accordingly, TES should be considered only secondarily as an energy cost reduction method, and primarily as a low capital cost peaking capacity enhancement.

    - The siting of TES should consider locations remote from SWAC heat exchanger stations and chiller plants, in order to further enhance the design and cost of the DC distribution system.

2. Much of the initial development effort should be focused on the high cooling density areas along Oahu's South Shore, where the largest loads, and therefore the greatest potential energy and environmental benefits can be captured, and also where earlier analyses identified the best economics.

3. Other opportunities should be addressed as appropriate, with increased development focus being applied to interested large customers (such as DOD facilities) or to unique situations (such as large new commercial real estate developments, large future combustion turbine power plants, or developments near NELHA on the Big Island).

4. Candidates for an effective public-private partnership should be identified and apprised of the potential benefits. Seed funding should be sought and obtained to fuel an effective and timely execution of the critical initial development steps of planning, marketing, government and community education, design, permitting, financing, and sales activities.

5. Various mechanisms (e.g. investment tax credits, Act 221 tax credits, and TES tax credits, as well as bonus depreciation schedules, utility demand-side management rebates, and federal energy production incentives) each could generate very significant further enhancements to SWAC-TES DC project economics. These mechanisms should be investigated in enough detail:

   - to define which may be realistic,
   - to quantify the value to be gained, and
   - to identify the necessary steps to ensure that the value is indeed captured.

6. SWAC DC systems should be actively pursued in Hawaii, in order to capture the technically feasible economic, environmental and community benefits associated with tapping the available deep ocean water cooling resource. The technology is so ready for deployment, and benefits are so substantial and apply to so many stakeholders, that SWAC-TES DC systems should be actively supported and pursued in Hawaii, to realize the ultimate vision and goal of 50,000 to 100,000 tons of installed system capacity.

Appendices

Appendix 1:
Bibliography - Literature Search of TES Technologies Applicable to SWAC-DC Systems

Appendix 2:
Summary Report of the Innovative Energy Systems Workshop, Honolulu, HI, March 19-21, 2003

Appendix 3:
Budgetary Quotations

Appendix 1

Bibliography - Literature Search of TES Technologies Applicable to SWAC-DC Systems

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Appendix 2

Summary Report of the

Innovative Energy Systems Workshop

Sponsored by the State of Hawaii
Department of Business, Economic Development, and Tourism (DBEDT)
Under a State Energy Program (SEP) grant
Provided by the U.S. Department of Energy

Honolulu, Hawaii – March 19-21, 2003

Reported by: John S. Andrepont, President – The Cool Solutions Company

Synopsis

The two-day workshop and optional third-day technical tour, addressed the status of evaluations and developments in the areas of Seawater Air-Conditioning (SWAC) and Kalina Cycle applications for Hawaii and elsewhere.

Over 70 attendees participated in the workshop, representing a cross-section of researchers, industry experts, representatives of interested private, military and other government facilities, engineers and equipment suppliers.

The workshop was both an exposition of detailed useful information and an interactive forum for discussion and exchange (indeed expansion) of knowledge.

One point of consensus was that the workshop was very successful for the attendees, providing new information and insights to all participants.

Major consensus was apparent in several key areas, as highlighted by certain observations:

- Technology developments are quite mature at this point. Demonstrations, and in many cases successful commercial installations, underscore the readiness for more widespread application.
- The cold water (deep ocean) resource is a unique advantage and opportunity throughout Hawaii.
- Hawaii offers numerous potentially beneficial uses of that resource.
- Benefits will accrue to users, developers, the community, the State, the environment, and others.
- Economic feasibility has now been demonstrated for many potential applications in Hawaii.
- Immediate effort should be focused on moving the technologies into commercial realization.
- A key element of successful commercial development could be the identification and formation of an appropriate Public-Private Partnership, along the models employed in other successful developments.

A detailed report of the workshop activities follows, focusing on the SWAC-related items. (Detailed information on the Kalina Cycle-related items can be found in an independent report prepared by Dr. Stephen K. Oney, Vice President of OCEES International, Inc.)

Day 1 – March 19, 2003

District Cooling, SWAC, and SWAC-TES Hybrids for Hawaii

Welcome and Opening Comments
Dr. David Rezachek, Alternate Energy Specialist – State of Hawaii DBEDT, ERTD

Dr. Rezachek provided a brief welcome to the attendees and an overview of the workshop.

District Cooling Systems – An Overview
Jack Kattner, CEO – FVB Energy, Inc.

Mr. Kattner, acting as a Director and past President of IDEA (International District Energy Association), provided a detailed overview of District Energy (DE) and the current trends in the DE industry.

- The concept of DE was presented, in which multiple buildings or facilities are heated and/or cooled, using thermal energy (steam, hot water, and/or chilled water) delivered to the customer facilities via piping networks.
- DE was stressed as a means of risk management for DE customers.
- DE is experiencing a lot of recent growth, on top of an already significant and technically mature industry.
- District Cooling (DC) serves to flatten customers' electric demand profiles.
- DC growth has been dramatic during the 1990s and since 2000.
- DE drivers include energy issues and costs and environmental issues. DE often serves as a key platform for the economic deployment of other technologies that benefit customer economics, energy efficiency and environmental emissions. Such technologies include Thermal Energy Storage (TES), cogeneration or Combined Heat & Power (CHP), thermal-driven chilling, hybrid chiller plants, alternate fuels, etc. Such technologies are often more readily and more economically employed in DE systems compared to individual building scenarios. In this way, DC may be key to deployment of SWAC.
- IDEA's "DE Space" collects IDEA members' reported data of new customers using DE services. This partial reporting of such data has totaled 225 million square feet of space from 1990 through 2001, or approximately 20 million square feet per year. Customer end-use types include: commercial offices, hotels, retail facilities, entertainment/cultural/sports facilities, convention centers, residential facilities, educational (school and university) facilities, healthcare (hospital and medical) facilities, government and institutional facilities, industrial & manufacturing facilities, and others.
- President Bush's Energy Policy was announced in the Spring of 2001 in St. Paul, Minnesota. The President cited District Energy St. Paul (DESP) and its DE/CHP system as a model of energy efficiency, energy diversity, and economy.
- Among the list of recent winners of IDEA's DE "System of the Year" award are DESP and Cornell University (noteworthy for its Deep Lake Source Cooling system).
- IDEA's nearly 1000 members represent a broad base of private and institutional DE system owners-operators, as well as suppliers and consultants to the industry. Members are primarily from North America, but also from dozens of countries around the world. IDEA produces a magazine, a newsletter and conferences and workshops. Additional information can be found on the IDEA website: http://www.districtenergy.org.

Project Financing for District Energy Systems
Scott Blumeyer, President – Norventus Group LLC

Mr. Blumeyer discussed the issues related to financing DE systems in general and Hawaii SWAC DE systems in particular.

- The SWAC feasibility analysis (Oct 2002) was referenced.
- Previously and recently, DC market analysis has been conducted for the Honolulu area.
- The technical precedent exists for both DC systems and for Deep Water Source DC systems.
- Government (State and Federal) mandates and support exist to encourage SWAC DC development.
- However, financial investment markets are generally "skittish" at present.
- Major barriers (per a recent IDEA/US DOE poll of universities) include:
    - Access to capital – a function of investor sentiment
    - Technical complexity – which impacts on the pro forma analysis
    - Market acceptance – dependent on the strategic sales cycle
- DE is an intersection of different things to different people. Relevant issues (and stakeholders) include: the energy play and real estate issues (users), economic development (local government), load management (local utility), and financial risk/reward (investors).
- A successful Finance Plan must: 1) be credible to DE investors, 2) strike a balance between cost of capital and covenants, 3) ensure a long-term funding commitment, and 4) result in a "close".
- The Capital Markets Equity Pool includes utilities, institutional, and investment funds.
- The Capital Markets Debt Pool includes institutional, commercial, and municipal.
- A potential resource would be a Public-Private Partnership (PPP). This would potentially offer: 1) improved access to land and rights-of-way, 2) a local component to complement mainland DC experience, and 3) an accelerated schedule for logistical issues. Examples of PPP include BOT (build-operate-transfer), BTO (build-transfer-operate), and perhaps most appropriately, BOO (build-own-operate). There are many precedents for the PPP approach, including water and wastewater treatment systems, infrastructure development (e.g. transportation), and indeed, DE systems.
- It is important to manage investor expectations and risk:
    - DE is not high-risk venture capital with high potential gains. Realistic and attractive returns are in the low teens.
    - Competitive debt rates are necessary.
    - The PPP approach helps with guarantors.
    - Coverage ratios should be attainable (by phasing development and investments, to the extent practical)
- Lessons Learned include the following necessities for successful financing: pre-sold long-term customer contracts, solid contract terms, credit worthiness of customers, and market sustainability.
- Also needed are DE management experience, DE marketing horsepower, and proven success stories.
- Recommended next steps for the Finance Plan for Hawaii SWAC systems include: 1) Developing a "qualifying prospectus", 2) creating a PPP, 3) confirming the financial market feasibility, and 4) if warranted, producing an offering memorandum.
- A precursor to the pro forma includes defining: 1) what the market will bear, 2) price point analysis to reflect customer perspectives, 3) differentiation of customer load profiles, 4) chilled water rate structure, and a real-estate comparison ($ per sq ft basis).
- A Case Study of a Downtown Honolulu SWAC DC development (Phase 1) was completed, with the following assumptions:
    - 8,465 Tons of customers (40% market penetration) over 3 years
    - $42 million in capital costs
    - A composite debt rate of 6.25%
    - Equity equal to 30% of CapEx
    - Minimum Return on Equity (ROE) of 13%
    - Minimum Debt Coverage Ratio (free cash flow over debt service or EBITDA/P&I) of 1.5
- Preliminary pro forma results through 3 phases were developed and are promising.

	Phase 1	Phase 2	Phase 3
Percent market share*	40%	60%**	80%
Customer Load (Tons)	8,465	12,700	16,930
CapEx (cumulative total)	$42 million	$48 million	$50 million
ROE	16.0%	19.0%	24.5%
Debt Coverage Ratio	1.5	2.0	3.0

(* Based only on the large potential customers in Honolulu.)
(** Anders Rydaker noted that DESP's DC system achieved 60 to 65% market share after 10 years.)

- The West Waikiki development can be expected to produce comparable results.
- Other issues (not yet factored into the pro forma above), could generate significant further enhancements, such as: 1) investment tax credits, 2) Act 221 tax credits, 3) TES tax credits, 4) bonus depreciation schedules (IRS willing), 5) utility rebates (potentially up to $650 per avoided peak kW), and 6) federal energy production incentives (potentially $0.015 or even $0.045 per kWh of avoided energy use).

Seawater Air Conditioning (SWAC), Cold Water Pipe Design, and a Brief Overview of Toronto Lake Source Cooling Project
Dr. Joe Van Ryzin, President – Makai Ocean Engineering

Dr. Van Ryzin reviewed key aspects of SWAC system design and implementation, and provided a brief summary of the Lake Source Cooling project in Toronto, Ontario.

- SWAC systems employ a heat exchanger (HX) to segregate the seawater piping system from the fresh water cooling network. The SWAC HXs are routinely plate-and-frame type HXs using Titanium plates for corrosion resistance to the seawater. The seawater piping is HDPE (High Density Polyethylene), also providing corrosion resistance.
- Experience with SWAC (and related Deep Lake Source Cooling) systems is already substantial: 5 pipelines installed in Hawaii since 1979, plus recently or soon to be completed systems at Cornell University, Toronto, and French Polynesia.
- Piping system deployment is a sophisticated, well-planned, rapid, and proven process.
- The recent installation at NELHA on the Big Island is a 3,000 foot deep, 55 inch diameter pipe with 39 ºF (4 ºC) seawater and 17,000 ton potential cooling capacity.
- Reasons to consider and employ SWAC include:
    - the right thing to do both economically and environmentally
    - simple and abundant (essentially unlimited)
    - 75 to 90% energy savings (and similar emissions reduction)
    - reduction or elimination of CFC and other refrigerants
    - addresses global warming concerns
    - economical today at some locations
- SWAC and Deep Lake Source Cooling applications include:
    - Cornell University, Ithaca, NY – 20,000 tons
    - Toronto, Ontario – 58,000 tons (under construction)
    - Halifax, Nova Scotia – 1,000 tons (very early system)
    - Sweden – urban systems using harbor water
    - NELHA, Big Island – 30 to 50 tons (plus numerous aquaculture and agriculture appl'ns)
    - Tahiti – underway
    - Curacao – underway
    - Korea – underway
- Toronto Lake Source Cooling
    - Combination system for District Cooling (DC) and municipal water supply

- 58,000 ton ultimate cooling capacity
  - 3 x 63 inch diameter pipes, 4 miles long, ~80m deep
  - Lake water flows: from lake – to filtration system – to DC HX – to municipal water system.
  - DC system water flows in a closed loop: from DC HX – to chilled water plant (for additional cooling) – to DC users – back to DC HX.
  - 75% projected energy savings (30 million kWh/yr)
  - Similar savings in refrigerants, CO_2, NO_x, and SO_2.
- Relative to conventional AC systems, SWAC has a major increase in capital investment, but a dramatic reduction in energy costs. Total life cycle costs are significantly reduced with SWAC.
- Ideal conditions for SWAC:
  - coastline near deep water
  - cooling customers near to shore
  - high annual cooling usage
  - high local electric costs
  - large systems (benefiting from economy-of-scale)
  - new construction
- Required DC system operating temp impacts system design and cost:
  - Lower temps require deeper, longer, costlier pipes
  - High pipe cost dictates "preservation" of the minimum available temp
  - If necessary, conventional chillers can used in series with SWAC (as in Toronto)
- SWAC system Delta T can be increased, improving economics, through secondary uses of the warmed (but still cool) seawater.
- Attractive SWAC sites have been identified, especially on Oahu, where 50,000 tons are realistic:
  - West Coast – very near to deep cold water
  - Honolulu – requires longer cooling pipes, but a dense collection of large cooling demand
  - Kakaako – new development, large demand, few key decision-makers (however, 4+ miles to 500 m deep water, but can be supplemented with chillers and Thermal Energy Storage.
- SWAC can be developed within Hawaii now <u>and</u> can be an export technology for Hawaii.

<u>Cornell Lake Source Cooling Project</u>

W. S. (Lanny) Joyce, Manager of Engineering, Planning and Energy Management – Cornell University

Mr. Joyce provided an overview of the Cornell University's Lake Source Cooling (LSC) project, including the project's history, installation, challenges, and success. (Additional detail can be found at the website: http://www.utilities.cornell.edu.)

- Reasons to employ LSC at Cornell
  - 40,000 lbs of CFC eliminated or recycled
  - energy efficiency (over 80% energy savings)
  - decreased reliance on fossil fuels (reduce pollution, acid rain, global warming)
  - cost-effective over the long-term ($58 million in capital for a 20,000 ton LSC system, 10 to 13 year payback)
  - community benefits
- Existing campus cooling infrastructure prior to the LSC project included:
  - an 18,000 ton DC system
  - 3 chilled water plants with 8 large electric centrifugal chillers
  - a 4.5 million gallon chilled water TES tank
  - chilled water supply and return (CHWS/R) tempos of 45/60 ºF
- LSC system facts and figures:

    - Relatively nearby access to the deep cold water of Cayuga Lake (one of the Finger Lakes of upstate New York)
    - Offshore pipe – HDPE, 63 inch diameter, 10,400 long, 250 ft deep (39 to 40 ºF water temp)
    - HX station – producing 45 ºF CHWS for campus (in architecturally attractive building at the lake shore)
    - Onshore CHWS/R transmission piping – 12,000 ft long (3,000 ft in a city street), rising to 450 ft elevation above the lake
    - New CHWS/R headers on campus – 42, 36 and 24 inch diameters, direct-buried, un-insulated, carbon steel with HDPE outer coating (for corrosion protection), connecting at 5 points to the existing 11-mile campus DC piping network
- The university review & approval process included, and went beyond, normal steps for large projects:
    - Master planning
    - Scientific and engineering oversight
    - Faculty involvement
    - Advisory group of university officers and trustees
    - Peer consultant review (over $100,000)
- Community benefits played a major role in community acceptance of the project, e.g.:
    - Ithaca High School saves $750,000 from LSC (in exchange for a right-of-way)
    - New sidewalks
    - Local employment for the construction ($20 million)
    - New lake shore park for the town
    - Bonding fees
    - Early groundwork within the community was critical to project acceptance
- The permitting and review process was extensive:
    - 17 or 18 required, specific to the locale
    - Federal – including wetlands, endangered species
    - State – including water discharge (toughest of all), historical preservation, department of transportation
    - Local – including various town, city, and county permits and reviews
    - Approximately $3 million in total cost
- Cornell's seasonal climate results in only a 20% annual cooling load factor. Hawaii's much higher annual cooling load factors (60 to 70%) will improve system economics further.
- Cornell LSC saves 87% in cooling energy use (~25 million kWh/yr).
- Cornell LSC system design life is 100 years.

Panel Discussion No. 1 – Identifying Barriers to Implementation
Kattner, Blumeyer, Van Ryzin, Joyce, and Anders Rydaker, President – District Energy St. Paul (DESP); moderator: Andrepont

The morning's speakers, accompanied by Mr. Anders Rydaker, President of DESP (the District Heating & Cooling system serving St. Paul, MN), answered questions from the attendees and identified important barriers to successful SWAC system development.

- Barriers very common to conventional DC developments:
    - High capital needs (chiller plants and DC piping network)
    - Introducing a new "outsourced" cooling concept to potential customers
    - Apprehension of reliance on a locally "new" technology
    - Achieving a "critical mass" of customers
    - Need for long-term customer commitments
    - Costly construction of a DC network in a congested urban environment

    - Need for support from local government and community for logistics of project
    - Note that these barriers, though significant, have frequently been successfully overcome.
- Barriers unique to Hawaii SWAC DC developments:
    - Even higher capital needs (seawater piping)
    - Apprehension of reliance on an additional perceived "new" technology
    - Need to combine local champions with very distant (mainland) experience and expertise
    - Note that these barriers are not different in kind, but merely different in degree, from the common barriers to DC noted above that are frequently overcome

Lunch Videos – Cornell Lake Source Cooling Project (Cornell University)

Two videos were presented:
- a promotional video summary of the project and its benefits
- video footage of project construction activities

Basics of Plate Heat Exchangers
Elizabeth Wheeler, Senior Application Engineer – Invensys APV

Ms. Wheeler briefly reviewed the concepts and details of plate-and-frame type HXs, a common element of SWAC systems.

- Plate HXs provide key benefits (versus shell-and-tube type HXs):
    - Compact, lightweight
    - Thermal efficiency, low cost
    - Potential for very low approach temperatures (critical for SWAC economics)
    - Expandability
    - Ease of maintenance
- Plate HXs are ASME Section VIII Division 1 pressure vessels, with standard operating pressures to 150 psig (and high pressure units available to 450 psig) and operating temperatures to 350 ºF.
- The narrow clearance between plates mandates the use of relatively clean fluids.
- Any leaks from one flow stream past plate-to-plate gaskets flow to atmosphere, rather than into the other flow stream.
- For SWAC applications, plate HXs employ Titanium plates and standard Nitrile (NBR) gaskets.
- Plate HXs are commonly used in conventional DC applications.

Downtown Honolulu Ice Storage-District Cooling Project
Jack Kattner, CEO – FVB Energy, Inc.

Mr. Kattner presented a detailed review of the issues associated with DC development in general and a Honolulu DC development in particular.

- Any potential DC market is continually evolving (new buildings, CFC chiller replacements, etc.).
- There are unique individual customer situations.
- DC opportunities include: old chillers, CFC chillers, additional regulations, capital needed for core business.
- Possible solutions: stockpile CFCs, rebuild/replace chillers, or outsource to DC.
- DC eliminates: capital drain, O&M concerns, environmental risk, focus on non-core business.
- DC provides availability of cooling service 24 hrs/day, 365 days/yr.
- DC is environmentally sound: energy, emissions, CFCs, noise, vibration, cooling tower plumes, CO_2/global warming, etc.

- DC-served buildings are easy to own, to operate, and to sell.
- DC creates predictability in capital budgeting.
- DC provides extremely high reliability. (Rydaker noted that DESP's DH system has experienced only 20 minutes of downtime in 20 years, i.e. 99.9998% reliability, much superior to the typical reliability of local electric utilities.)
- In N. America, there are now over 40 urban DC utility systems and ~2,000 institutional DC systems (universities, hospitals, airports, military facilities, etc.), plus other DC systems in Europe and Asia.
- The growth rate of DC systems is over 15%/yr. Activity has been especially high since 1990.
- DC is a catalyst for economic development in urban locales and central business districts.
- DC developments can be led by: electric or gas utilities, municipalities, independent private developers, customer co-operatives, or hybrids. Hawaii SWAC DC probably will require a strong public signal to investors; therefore, a PPP may be an appropriate approach.
- Typically necessary elements for success (from experiences with over 40 DC utility developments):
    - Educate and energize community leadership (public <u>and</u> private) – A must!
    - Meet customer needs through the DC service – More than just air-conditioning; capital avoidance, reliability, no surprises, ease to own & operate, 24/7 operation, cooling for special events and after-hours, data center cooling, etc., and risk management.
    - Allow 14 to 18 months from commitment to begin operations – Need to develop "anchor" customers or a "critical mass". The process includes: a "business appreciation" study, technical and financial feasibility analyses, service agreement (contract) terms, customer discussions (repeated again and again and again), and an investor/developer who can hold a steady course throughout.
    - Focus initially on downtown / CBD – For Hawaii, focus on downtown Honolulu CBD. Other high load density areas can also be attractive: campus areas (education, medical, government, industrial), convention/hotels, sports/entertainment.
- DC project elements include:
    - Targeting the market area (as defined above)
    - Selection of the source(s) of cooling - central chiller plants, TES, deep lakes or ocean, select existing customer chillers, and <u>creative</u> hybrid combinations, including phasing over time
    - Selection of distribution network details – piping material (carbon steel, ductile iron, HDPE), monitoring of water quality and quantity
    - Connections to customers – direct vs. indirect, HXs, metering, controls
- Phased development – important generally, and also for Honolulu.
- DC development example – Entergy DC – New Orleans, LA
    - Serves anchor customer: NORMC (New Orleans Regional Medical Center)
    - 32,000 ton peak capacity – from 20,000 tons of chillers and 62,000 ton-hours of ice TES
    - Expandable into the New Orleans CBD in future
- Deep water DC system examples include:
    - Cornell University and Toronto
    - Stockholm, Uppsala, and Norrengi in Sweden, and 2 others in Scandinavia
- Typical DC system operating temps are CHWS of 34 to 40 ºF and CHWR of 50 to 54 ºF.
- Summary of benefits from Honolulu DC:
    - Customers' capital and capital risk (predictability)
    - O&M risk – maintenance/repairs, chemicals, water, security, noise, insurance, space
    - Quick response, 24/7, low-load cooling, after-hours cooling, comfort (if lower CHWS temp), meter/monitor/assist customer (reduce in-building energy use)
    - Reliability, industrial grade equipment, TES, redundant capacity/distribution
    - Environmental – refrigerants, water treatment, noise, vibration, etc.
    - Supports municipal economic development
    - Helps relieve stress on HECO's electrical distribution system

- In short, DC will be good for its customers, for Honolulu, and for Hawaii.

<u>Results of the Hawaii SWAC Feasibility Analysis</u>
Dr, David Rezachek, Alternate Energy Specialist – State of Hawaii DBEDT, ERTD

Dr. Rezachek summarized the findings of the SWAC Feasibility Analysis, which were published in the October 2002 Final Report. The full text of the report can be found at the website: http://www.hawaii.gov/dbedt/ert/swac.html.

- Objectives of the Study
  - Identify potential areas for SWAC applications
  - Update previous feasibility studies
  - Conduct preliminary technical and economic feasibility analyses for other locations
  - Prioritize the locations for further analysis
  - Develop a Marketing Plan to allow private sector development
  - Identify types of assistance that can be provided by the State of other government sources
- Areas Evaluated – 6 on Oahu and 4 on neighbor islands
  - Primary cooling demand areas on Oahu are not within practical reach of 1,000 m (3,300 ft) 4 ºC (39 ºF) water depth, but are within reach of 500 m (1,600 ft) 7 ºC (45 ºF) water depth.
  - Downtown Honolulu Waterfront, Kakaako, Waikiki are primary areas.
  - Other areas include UH-Manoa (with Waikiki), Pearl Harbor Naval Shipyard (PHNS), and Kaneohe Marine Corps Base Hawaii (KMCBH), as well as areas on Kauai.
- Economic Analyses
  - Employed the EPRI Technical Assessment Guide (TAG) method of analysis
  - All SWAC assumptions were purposely chosen to be reasonable worst case conservative
  - Even so, Honolulu Waterfront, Kakaako, and Waikiki cases showed lower life cycle costs for SWAC (10 to 20% below costs for conventional cooling).
  - UHM-Waikiki, PHNS and KMCBH had somewhat higher life cycle costs for SWAC versus conventional cooling.
  - Sensitivity analyses were conducted to explore the impact on economic results.
  - Numerous alternate assumptions have the potential to individually reduce life cycle SWAC costs by approximately an additional 10%. Such factors include: capital cost contingency, interest rates, real escalation rates of electricity costs, income tax rates, Federal investment tax credits, depreciation rates, utility DSM incentives, Hawaii Energy Conservation Income Tax Credit, energy production incentives, and property taxes.
  - Potentially realistic combinations of these alternate assumptions could result in reductions in life cycle SWAC costs by more than 50%. Thus, even many non-primary sites may be economically practical for SWAC.
- Other Benefits of SWAC
  - SWAC systems save 90% of cooling energy use
  - SWAC systems save 4,500 kWh/ton-yr (and 8.4 Bbl of imported oil per ton-yr)
  - These savings were extrapolated for each of the areas studied.
  - A 50,000 ton SWAC DC development (very practical for the Downtown-Kakaako-Waikiki area) yields energy and oil savings equivalent to 70,000 residential solar water heaters.
  - Significant reductions in greenhouse gas emissions and other air and water pollutants
  - Avoids use of harmful chemicals (refrigerants) in conventional cooling systems
  - Reduces water use and toxic chemicals associated with cooling towers
- Secondary Uses of SWAC Effluent
  - Economical and environmental uses of effluent (still relatively cool at 55 to 57 ºF)
  - Marine biotech industrial parks/facilities (cold water aquaculture)

    - Auxiliary cooling water for cooling systems, power plants, industrial facilities, etc.
    - Cooling of grounds, e.g. parks, golf courses (creating condensation and eliminating watering)
    - Discharge into brackish bodies of water, estuaries, canals, harbors, to improve water quality
- Conclusions
    - SWAC is simple, technically and economically feasible today, inexhaustible, renewable, and has minimal environmental impacts (indeed a major net benefit versus the alternative).
    - SWAC systems have great potential in Hawaii, statewide.
    - Hawaii has an estimated SWAC potential of over 100,000 tons, more than 50,000 tons in the Waikiki-Kakaako-downtown Honolulu area.
    - Those primary areas are economically attractive, even under conservative base case assumptions, with levelized life cycle cooling costs 18% below conventional cooling costs.
    - Sensitivity analyses show cases with even better economics, in some cases with over 50% cost savings. Thus many of the non-priority SWAC areas in Hawaii may also be economical.
    - Thus, SWAC customers and developers/investors can reap economic benefits.
    - Other benefits include reductions to greenhouse gas emissions, air and water pollution, harmful refrigerants, and cooling tower chemicals & water use.
    - Secondary uses of the 55 to 57 ºF effluent are numerous, economically and environmentally beneficial, and can aid overall system economics.
    - The best system for Hawaii (and elsewhere) may be a hybrid SWAC-TES DC system, which would increase capacity factor of the piping, increase peak load served, and lower capital cost per ton served.
    - SWAC will significantly reduce peak utility demand and reduce cooling energy use by 80 to 90%.
- Recommendations – to move the potential projects into commercial realization
    - Conduct a follow-up study to analyze integrated SWAC-TES DC systems. (This study is underway. See the summary of the presentation immediately below.)
    - Conduct more detailed site-specific evaluations for each of the positive and marginal (base case) sites identified in this study.

<u>Preliminary Results of the SWAC-TES Project</u>
John Andrepont, President – The Cool Solutions Company

Mr. Andrepont presented a brief overview of Thermal Energy Storage (TES) and its applications in DC systems, and a summary of the results to-date from the study of integrated SWAC TES DC systems for Hawaii.

- Overview of TES
    - Latent heat, i.e. ice TES, versus sensible heat, i.e. chilled water (CHW) or low temp fluid (LTF) TES – each has inherent characteristics and thus inherent advantages and limitations.
    - TES already widely used in DC applications – private industry DC, universities and colleges, hospital and medical facilities, other government facilities, DC utility systems, and Combustion Turbine Inlet Cooling (CTIC).
    - TES reduces operating costs (by shifting energy use to low-cost off-peak periods) <u>and</u> often reduces capital costs (by meeting peak cooling loads with a combination of TES and a smaller than conventional chiller plants).
- SWAC-TES project concept and objectives
    - Study builds on previous results
    - Ultimate objective – to commercialize SWAC systems for Hawaii, and as an export
    - Hybrid SWAC-TES DC systems allow
        1. larger peak cooling loads to be served by a given SWAC pipe

2. smaller SWAC piping to be used to meet a given peak cooling load
3. improved system economics, and thus improved chance to realize and capture SWAC benefits

- SWAC-TES project tasks and results to-date
    - Task 1 – Review and analysis of earlier SWAC report
        - Assumptions generally valid and appropriate, if conservative
        - Most SWAC systems would benefit from integration of TES
        - Should reconsider contingency levels, incorporate operating personnel savings, and pursue SWAC DC with TES.
    - Task 2 – Literature search of TES applicable to SWAC
        - Reviewed, analyzed and summarized 6 design guides/handbooks, 30 case studies/analyses, and info from 8 TES equipment suppliers.
        - Identified numerous DC applications of TES in industry, institutions (educational, medical, and government), DC utilities and CTIC. Analyzed and evaluated types and sizes of TES technology employed.
        - All TES types (ice, CHW, and LTF) are used in DC.
        - CHW TES most often used in large DC - economy-of-scale, ease of retrofit with existing systems, and can be sited remotely from chillers.
        - Also, SWAC temps are too warm for directly recharging ice or LTF TES.
        - CHW TES best suited to SWAC DC, though all types of TES can be used.
    - Task 3 – Economic Analysis
        - Prelim results for a combined Honolulu Waterfront-Kakaako-Waikiki SWAC DC system – 24,000 ton peak met with 17,000 tons of SWAC plus 51,000 ton-hrs of CHW TES, resulting in 10 to 15% savings versus the non-TES SWAC base case.
        - Prelim results for an East Waikiki-UHM SWAC DC system – 7,800 ton peak met with 6,900 tons of SWAC plus 6,000 ton-hrs of CHW TES at UHM, resulting in smaller piping and ~12% savings versus the non-TES SWAC base case.
        - Promising candidates also include Kakaako (new developments), and West Oahu (deeper colder water and new development, industry and future CTIC potential)
    - Task 4 – Preliminary Design – to be completed
    - Task 5 – Marketing Plan – to be completed
        - Must address key anchor customers, plus all stakeholders, and benefits to all.
        - Stakeholders include – customers, engineers, affected community, general public, government, local permit authorities, local electric utility, auxiliary service users, equipment suppliers and contractors, and investors.
    - Task 6 – Financing Mechanisms – to be completed
        - Consider development via private, public, and PPP means
    - Task 7 – Innovative Energy Systems Workshop
        - Assistance in workshop planning, execution, and reporting
    - Task 8 – Final Report – to be completed, June 2003.
- Moving SWAC to commercial reality
    - Major barriers do exist – new concepts, a new business, capital investment, long-term outlook, creating “critical mass”, and finding a committed developer.
    - But there is much reason for optimism – numerous recent DC successes, unique resources and opportunities in Hawaii, proven local technologies and talent, energy and environmental mandates, avoided oil risks, positive economics further improved with TES, private and public interest in the development.
- Summary and Conclusions
    - Enormous benefits from SWAC
    - SWAC long used with harbor water (in Halifax, Nova Scotia and in Sweden)

    - Deep Lake Source DC, using Hawaiian technology (at Cornell U. and Toronto)
    - Unique potential in Hawaii – deep water access, over 100,000 ton potential, and mitigation of imported oil risks
    - TES a natural complement to SWAC, especially using CHW TES
    - Prelim results show 10 to15% improved economics with TES, and thus improved chances to realize commercialization
- Recommendations
    - Identify and address all significant barriers – to DC in general, to SWAC specifically, to Hawaii in particular, and specific to individual developments and customers.
    - Incorporate TES in SWAC designs to improve economics
    - Market the benefits of SWAC to <u>all</u> stakeholders

The benefits are much too great – not to persevere and <u>turn the vision into a reality</u>.

<u>Overview of a Successful Public-Private Partnership District Energy Development</u>
Anders Rydaker, President – District Energy St. Paul

Mr. Rydaker presented a brief overview of the District Energy development serving St. Paul, MN. (Additional detail can be found at the DESP website: http://www.districtenergy.com.)

- The DESP system was started with strong support from the then mayor.
- DESP was initially started as a DH system, using hot water distribution (on the European model).
- Later, DC service was added. The DC system has grown steadily from its start over the last 10 years, now serving 60 to 65 DC customers (~20,000 tons). Customers are both public and private facilities representing a 60 to 65% market share in the St. Paul CBD and government (State Capitol) district.
- The central plant has HW boilers (firing coal, oil, gas, and wood waste) and chillers (electric centrifugals and some absorption), plus a 2.5 million gallon chilled water TES tank.
- A new satellite chiller plant is on-line this spring with an additional 6,000 tons of electric centrifugal chillers and a 4 million gallon chilled water TES tank.
- Existing chillers at a few select customer buildings are contractually controlled by DESP for use as peaking and back-up chiller capacity (though rarely if ever operated).
- The most distant customers are 25 city blocks of piping distance from the main chilled water plant.
- The DESP system is a not-for-profit co-operative owned by its customers. Customers elect 3 of the 7 members of the Board of Directors.

<u>Panel Discussion No. 2 – Overcoming Barriers to Implementation</u>
Wheeler, Kattner, Rezachek, Andrepont, and Rydaker; moderator: Van Ryzin

The panelists answered questions from the attendees and discussed approaches to overcome barriers to implementing SWAC DC in Hawaii.

- There was clear consensus that, although there are significant barriers to the implementation of SWAC DC systems in Hawaii, the barriers are no different in kind, and only somewhat different in degree, to the barriers that are routinely overcome in other successful DC developments.
- Technical feasibility is not an issue, neither for the offshore SWAC subsystem nor for the onshore DC system. Past successes demonstrate the feasibility and will be a special aid the marketing effort.
- A broad-based determined marketing effort, and attention to unique individual customer needs, will be crucial in securing a critical mass of customers.
- Those anchor customers and their long-term commitment will be necessary to securing project financing/investment.
- A Public-Private Partnership (PPP) is a likely attractive mechanism for a successful development.

- Positive local government decisions will be key in moving the development into reality, e.g. one or more of the following:
    - Commitment to actively participate in the system ownership/development team
    - Assistance in educating the community regarding the numerous benefits to customers, the community, the environment, imported oil risk, etc.
    - Commitment to employ DC service in local government buildings.
    - Assistance with permitting and rights-of-way approvals
    - Consideration of and commitment to appropriate investment tax credits
    - Consideration of and commitment to appropriate DSM utility incentives
    - Consideration of and commitment to appropriate energy production incentives
    - Consideration of and commitment to appropriate property tax assessments
    - Consideration of and commitment to appropriate depreciation schedules

Day 2 – March 20, 2003

Waste Heat, the Kalina Cycle, and Kalina Cycle Applications in Hawaii

Welcome and Opening Comments
Dr. David Rezachek, Alternate Energy Specialist – State of Hawaii DBEDT, ERTD

Dr. Rezachek provided a brief overview of the days activities.

The Kalina Cycle – Description and Applications
Yakov Lerner, VP of Engineering and Projects – Recurrent Resources LLC

For details of this presentation, see Dr. Stephen Oney's independent summary report of the workshop.

Preliminary Results of Hawaii Kalina Cycle Feasibility Analysis
Dr. Stephen K. Oney, Vice President – OCEES International, Inc.

For details of this presentation, see Dr. Stephen Oney's independent summary report of the workshop.

On-Going Kalina Cycle Developments
Dr. Hans Jurgen Krock, President – OCEES International, Inc.

For details of this presentation, see Dr. Stephen Oney's independent summary report of the workshop.

Panel Discussion No. 3 – Kalina Cycle Developments
Lerner, Oney, and Krock; moderator: Rezachek

For details of this discussion, see Dr. Stephen Oney's independent summary report of the workshop.

Deep Ocean Water Applications Facility
Dr. Manfred J. Zapka, Senior Project Director – Marc M. Siah & Associates

For details of this presentation, see Dr. Stephen Oney's independent summary report of the workshop.

<u>Lunch Video – District Energy is the Link (International District Energy Association)</u>

The IDEA's informational and promotional video was presented, illustrating:
- District Energy concepts
- Benefits to DE customers
- Benefits to energy efficiency and emissions
- Extent of the DE industry, in the U.S. and worldwide

<u>Panel Discussion No. 4 – Facility Owner-Operator Feedback</u>
Workshop attendees representing Hawaiian facilities (Mr. Kevin Saito – Utilities Manager and "landlord", US Navy PHNSY Energy Services Division, Mr. Gary Shimabukuro – Acting Energy Manager, US Navy PHNSY & IMF, and representative of the State of Hawaii DAGS, managing a $3 million/yr energy budget for Honolulu area State buildings); moderator: Andrepont

- DAGS representative stated that SWAC/TES was a possibility. However, he's concerned with low (6 ºF) delta T in his facilities. (Anders Rydaker: DE utilities work with building owners to improve controls and economics within customer buildings. John Andrepont: To achieve a better Delta T, there is often an incentive (carrot & stick) built into the DE rate structure. Addressing the low Delta T issue is most important during hot weather, high load conditions.)
- Navy hasn't moved much beyond basic energy efficiency – but they have been interested in SWAC.
    - PHNSY use of SWAC/TES – distance to deep cold sea water too great – but SWAC may be feasible with complementary chillers.
    - Military utility services – many offices that don't talk to each other and don't even know what each other does.
    - It is expected that the Navy will eventually have some sort of District Cooling.
    - Earlier explorations of SWAC identified challenges – This workshop answered some of their questions. (There should be follow-up to understand and explore any remaining questions.)
- Top SWAC DC candidates will be the most receptive customers. For example, even though PHNSY was not in the Top 3 (of potential sites), their desire to potentially use DE it is a major advantage. (Anders Rydaker: Once DE has initial customers, they help to sell it to others, enhancing marketing and market penetration.)
- Other potential benefits of DE are of interest to the facility managers, e.g.:
    - Most of the Pearl Harbor infrastructure is pre-WWII and needs replacement or upgrading.
    - Military is also consolidating facilities for greater efficiency.
    - However, DAGS has already changed-out many chillers, and installed T8 fluorescent lights with electronic ballasts.
    - Currently facilities managers have no peak demand control.
    - There are many "ancient" motors and pumps (and also high heat generation). They plan to add cooling. However, trenching to these loads is a concern.
    - Need to air-condition ships while in dry dock.
    - Real-time monitoring of cooling use is currently lacking. How best to actually measure a building's energy use? Need feedback on energy use. Could use a real time energy metering/monitoring system, as would be provided by DE. Drive behavior by measuring use and letting people know this information.
- Note: any technical or commercial solutions cannot affect the mission of military facilities. They must support that mission.

- Anders Rydaker: DESP maintains on-line communication with each and every customer – every seven minutes, they get a data point. Customers have access to the data. This real-time monitoring helps to keep DE system and customer costs down.
- The Navy of course does have some particularly critical cooling loads. An 1,800 ton chiller plant serves a part of the PHNSY loads. They have a computer center with 24/7 operation and cooling needs.
- Anders Rydaker: DE systems don't want to sell the customer too much contracted load, or too little. Customers who have are penalized (for too much cooling demand or for too little Delta T), aren't happy customers; accordingly, DE systems work closely with their customers to get it right.
- Public-Private Partnership (This can include the DE consumers themselves, as it does in St. Paul.) – DE consumer has some buy-in to the system. There is a mutually beneficial relationship. Do need to put in some contract clauses (as in all DE contracts).
- Anders Rydaker: DESP has a seven member Board of Directors, three of whom are elected by customers; thus, the customers have a strong voice on the board.
- Potential "deal-breaker" issues or items that need to be addressed:
    - Need money (rebuilding an infrastructure as large as Pearl Harbor is very expensive)
    - Operating costs may not decrease, because operating budgets don't include capital allocation. Closing a DE deal usually requires getting the capital guys (and their budgets) together with the operating guys (and their budgets).
    - Need to do due diligence.
    - Need to properly present (identify, estimate, and quantify) the benefits

Panel Discussion No. 5 – Recommended Next Steps for Realization
All workshop participants; moderator: Andrepont

The following suggestions were offered by all the attendees, in answer to the question: What should/must be done or addressed in order to move these technologies forward into commercial implementation quickly and effectively?

- Team building – a Public-Private Partnership.
- Public-Private Partnership.
- Reb Bellinger – give a presentation to PAC/DIV.
- Don't take all of this knowledge and put it on a shelf.
- Federal government should provide funding (DAGS representative).
- Finances is a focal point – Navy/Barbers Point redevelopment – looking for private sector funding.
- Government to provide land, etc. with financing from financial partners / other participants.
- Communication to others (beyond end users), e.g TES will be highly visible (we must address siting and aesthetics).
- Huge capital required – difficult to find locally – wants federal government to fund – doesn't think that it can be funded locally.
- Public education.
- Educate people so that they know they are part of the PUBLIC-PRIVATE PARTNERSHIP.
- Complete the model. This allows one to sit down and show what it would look like, how stakeholders will benefit – benefits/challenges. Need a good focal point. Time line. Dollar costs. Cost shares. Sources of funds. Need to create a "sense of urgency". Otherwise in 10 years will just be repeating everything.
- Concentrate on key players, e.g. State, military, and large land owners. Keep pecking away at them. Need to go around and convince these people. Web site can be a huge source of data regarding SWAC/TES – everything there for information. Similar to Cornell's web site.

- Huge value. All data goes on to web site. Link to Cornell. E-mail, phone number, fax number – now full blown.
- Distance learning. Asynchronous vs. just web site.
- Community building – networking.
- Web site needs to be very interactive and motivating. Needs to have certain learning ingredients.
- Employ "Educommerce" – offer learning on a commercial web site.
- Workshop – have more of these. Workshop with main players – develop strategic business plan – overarching goals and tie into public policy. DBEDT web site a good starting point. Help with networking/marketing.
- Work on an implementation plan from the overarching goals.
- Lots of work and information. Reports. Studies. What are the compelling set of questions/concerns that cause someone to take action. Does it work? Yes. What other motivators are there? Difficult but necessary to get people to make a change in their behavior. Define a set of compelling issues that will make the PUBLIC-PRIVATE PARTNERSHIP go forward.
- Get correct individuals – education (key), but it needs to be substantive, consistent, cohesive. Consumers as well as local political forces. Time line is very important. SWAC has many benefits. Greatest motivator is a deadline. Act 77 perspective. We have to develop some realistic timelines as a motivating tool.
- Issue that needs to be addressed: Avoided cost needs to be re-evaluated. Intermittent technologies and their value. Baseload renewables are offered only avoided energy costs.
- All for education. General education from a web site is really central. When people search for an answer, they use the web.
- People from all over the world have gone to the web site. Web site is critical and effective. It's believable. Other than that, what do we do? What to do next? Find niche market that is commercially-viable without federal funding. We don't need another demonstration.
- Diego Garcia is a good first start for OTEC. There are several islands with severe water (and electricity) problems and costs. Focus on places with significant costs for air-conditioning. Other markets (beyond Hawaii) may be best first.
- Complete systems approach. Will proceed when someone goes first.
- Puna Geothermal will be a good initial Hawaii Kalina cycle project.
- Need a champion.
- Put together a selection process and choose a business model. Choose one and go with it.
- Talk with important environmental stakeholders. Talk to them and get them to be supporters.
- The distribution system.
- Public education important. Politicians will follow the public.
- Where will we put the pumping station? How do we get these landowners on board?
- Technologies are available. SWAC and TES have been proven elsewhere. Convinced that the load is there and that this can be a commercially-viable proposition. Therefore, we next need a PUBLIC-PRIVATE PARTNERSHIP – What kind? How do we do it?
- How were they developed? In the same position as us 20 years ago. Need to get key players to understand the benefits. Need to get a champion to promote them.
- No doubt that this could be a success economically. But decision-makers don't have all of the information available.
- Seed money is necessary. Some U.S. Department of Energy money may be available.
- Where are we now in the process (how far back are we from Cornell's project success)? Lanny Joyce:
    - We are very early in the process.
    - In the first year, Cornell spent $250,000.
    - Used a two-day intensive charrette. Team fresh off the Lake Source Cooling design.

- 30-year master plan.
  - Immediately launched into environmental permitting and approval process.
  - Started out very early talking with community. Survey, three years into the project, showed only 13% were aware of this concept.
  - Quite a process. Community outreach and environmental impact assessment process was real cost. (Anders Rydaker: As another example, for the new Combined Heat and Power (CHP) project using biomass, DESP conducted 32 community meetings involving hundreds of people.) Mental filtering. Remember, a very small number of individuals in the community can make your life miserable.
- Get focused. Put packages and targets in front of people. But as part of that, note that there are very significant impacts the on bottom line made by various parameters (e.g. investment tax credits, utility DSM incentives, energy production incentives, property tax rates, and depreciation), each with ~10% improvement in bottom lines. Such treatments are realistic and have precedents, e.g. why a $650/kW utility rebate is justifiable. We need to explore deeper into and pin-down these issues. Confirming even one or two can move the developments into slam dunk financial winners.
- Need additional participation from the State and city/county and federal governments. They need to understand the great benefits of SWAC. News to all of us, before we were educated. Kudos to BOW and Dave Rezachek for their efforts to-date.
- Marketing plan should address all stakeholders. It needs to be consistent in its main message, but with a different focus and approach for different stakeholders.
- Canada has greatly increased its District Energy systems. Action was needed to be committed and was committed by Canadian municipal governments. DE infrastructure is seen as a similar responsibility for cities in Sweden.
- Let's go find out what's going on.
- Sense of action that needed to be taken. People's behavior needs to be changed. Need to get to the point where people ask: why <u>aren't</u> we doing this? Not – why should we do this?
- Stop studying this to death. Do something now. For example, set a goal of installing 100,000 tons on Oahu in 10 to 15 years. Identify the most likely initial system (e.g., downtown Honolulu). Then add systems to this (e.g., Kakaako). These systems can then be interconnected to provide for redundancy and reliability. Prepare a master plan for full development over the given time period. Let's get started NOW!

Day 3 – March 21, 2003

Optional Tour of NELHA (Natural Energy Laboratory of Hawaii Authority) – Keahole, Hawaii

The tour was attended by Dr. Rezachek of DBEDT, Lanny Joyce of Cornell University, and John and Karen Andrepont of The Cool Solutions Company.

<u>Tour and Discussion of NELHA</u>
Jan C. War, Operations Manager – NELHA

Mr. War provided an in-depth overview of the history and activities of the NELHA facility. Slides, poster-presentations, and a walking tour of some of the facilities helped to illustrate the varied activities.

- The newest and largest seawater pipeline at NELHA is a 55 inch diameter HDPE pipeline 9,000 ft long and 3,000 ft deep. It has the capability to deliver 4 ºC (39 ºF) seawater at a rate of up to 27,000 gpm. However, the initially installed pumping systems will only provide up to 7,000 gpm.
- NELHA also operates warm (surface) seawater intake pipes at 24 to 28 ºC (75 to 82 ºF). Most tenant users at NELHA employ blended water at temps of 16 to 18 ºC (60 to 65 ºF).

- NELHA charges tenants for their land, plus \$0.08/kgal for cold seawater and \$0.06/kgal for surface seawater. These current water tariffs cover incremental operating costs (but not the large initial capital costs). The tariffs may be increased somewhat in the future, especially as NELHA is under pressure to become self-funding.
- Andrepont noted that, if used at full capacity for cooling, and assuming a 15 ºF Delta T, the 55 inch pipeline could provide ~17,000 tons of cooling. The effluent temp would still be only 12 ºC (54 ºF),i.e. colder than temperature used by most NELHA tenants.
- Andrepont noted that, at least hypothetically, and based on the current NELHA cooling water tariffs, a cooling user could purchase deep cooling water at a rate of only \$0.008/ton-hr. And, if the effluent were returned and credited at the current warm water tariff (even though the effluent is still much colder), the net cost would be reduced to only \$0.002/ton-hr. (For perspective, "typical" DC tariffs in the mainland U.S. have a "consumption charge" (to cover marginal production cost) and a "capacity charge" (to cover capital and other fixed costs). The marginal consumption charges will generally be in the \$0.07 to 0.10/ton-hr range, or higher, with total costs to customers varying from \$0.20 to \$0.35/ton-hr, or more, depending on annual cooling load factors.)
- NELHA tenants all operate in parallel with each other. No one returns seawater into the cold water or surface water supply headers.

Tour and Discussion of Common Heritage (a NELHA tenant)
Prof. John Craven, Founder and Anne M.-O. Bailey, CEO – Common Heritage Corporation (CHC)

Professor Craven and Ms. Bailey reviewed the history of the development of NELHA and provided a hands-on tour of the on-going activities that Common Heritage is researching and demonstrating at their facility within NELHA.

- Among the many fascinating highlights of the discussion and the demonstrations was the hospitality of an unexpected and delightful luncheon comprised of items produced on the property using deep ocean water agriculture and aquaculture (salad, bread, and Maine lobster), plus deep ocean water-refrigerated beverages.
- Many of CHC's demonstrations are part of an integrated serial process of using the cold resource. (e.g. fresh water production, refrigeration and agriculture sequentially utilize cold resource sequentially.
- Ms. Bailey described CHC's vision and efforts to expand NELHA operations into an integrated (series-configuration) ocean cooling process. The concept would employ piping the cold seawater from the new 55 inch pipeline inland to the "top" of the NELHA property (an elevation of ~250 ft above sealevel), adjacent to the highway. The cold resource could then flow back through the NELHA property by gravity, meeting the needs of numerous diverse processes and users, in series where appropriate.
- Andrepont noted to Bailey that any significant air-conditioning loads at or near the Kona Airport or across the highway, now or in the future, could be very economically served by such a system. A large SWAC HX could be the first step in CHC's series configured integrated process.

Appendix 3

Budgetary Quotations

- Confirmation of Budgetary Quotation for Packaged Chiller Plants, TAS, June 6, 2003
- Confirmation of Budgetary Quotation for TES Tanks, CB&I, June 6, 2003

COOL $olutions

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June 6, 2003

Jerry Koch, Packaged Chiller Sales
Turbine Air Systems, Ltd.
4300 Dixie Drive
Houston, TX 77021

Re: Budgetary Quotation
Packaged Chiller Plants – Honolulu, Hawaii

This letter provides written confirmation of the budgetary quotation that we recently discussed.

Scope: Two (2) TAS packaged chiller plants, each provided on a turnkey design-build basis, installed in Honolulu, Hawaii, inclusive of the following:

- Trane centrifugal compressors using low pressure, R-123 refrigerant
- Chilled water heat exchangers (refrigerant evaporators)
- Seawater heat exchangers (refrigerant condensers)
- Chilled water (CHW) pumps and seawater condenser water(CW) pumps
- Electric motors and motor starters for the compressors and pumps
- All necessary interconnecting piping, valves, insulation, instrumentation, and controls
- Structural skids and climate-controlled housings with painted architectural cladding
- All code required accessories and accessibility for operation and maintenance
- Operation & maintenance manuals and start-up/commissioning supervision
- Standard warranties and performance per the specifications listed below

Performance Specifications (for each of two plants):

Chilled water capacity:	5,470 tons
Entering CHW temperature:	46.5 ºF
Leaving CHW temperature:	39.0 ºF
Entering CW temperature:	57.0 ºF (seawater)
Leaving CW temperature:	to be determined by TAS
CW flow rate:	to be determined by TAS
Maximum power usage:	0.5 kW per ton at full load, for compressors, CHW and CW pumps

Approximate Dimensions (for each of two plants): __ ft wide x __ ft long x __ ft high

Budgetary Price: $6,017,000. per chiller plant, installed cost.

Schedule: 6 months from award through completed installation.

Please let me know if there are any further clarifications. Thank you.

John S. Andrepont

John S. Andrepont, President
The Cool Solutions Company

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June 6, 2003

John M. Baer, Regional Manager
Chicago Bridge & Iron Company
1001 Galaxy Way, Suite 106
Concord, CA 94520

Re: Budgetary Quotation
Thermal Energy Storage (TES) Tank – Honolulu, Hawaii

This letter provides written confirmation of the budgetary quotation that we recently discussed.

Scope:
Two (2) CB&I Strata-Therm® chilled water TES tanks, each provided on a turnkey design-build basis, installed in Honolulu, Hawaii, inclusive of the following:

- Steel-reinforced concrete "ringwall" foundation
- Above-ground welded-steel tank, per AWWA D100 Code
- Internal primer and top coat of paint, plus external primer coat of paint
- External thermal insulation with vapor barrier and architectural, painted aluminum cladding
- Patented, non-corrosive, internal flow diffusers for proper stratification
- Internal welded steel piping for supply and return water to and from diffusers
- All code required accessories, shell and roof manways, and roof access
- Twenty (20) temperature sensor (thermowell) fittings, spaced vertically along the shell
- Thermal performance guarantees per the specifications listed below

Performance Specifications (for each of two tanks):

TES capacity:	41,600 ton-hours
Peak discharge rate:	6,000 tons
Peak recharge rate:	6,000 tons
CHWS temperature to tank:	39.5 ºF
CHWR temperature to tank:	58.0 ºF
Maximum heat gain:	2% of TES capacity per 24 hours, at ASHRAE 0.4% dry bulb temp
Maximum pressure drop:	3 psi, inlet flange to outlet flange, at peak flow rate

Approximate Dimensions (for each of two tanks):
104 ft diameter x 60 ft shell height (3.82 million gallons, gross shell volume)

Budgetary Price: $1,910,000. per tank, taxes excluded.

Schedule: Not more than 12 months from award through completion.

Please let me know if there are any further clarifications. Thank you.

John S. Andrepont

John S. Andrepont, President
The Cool Solutions Company